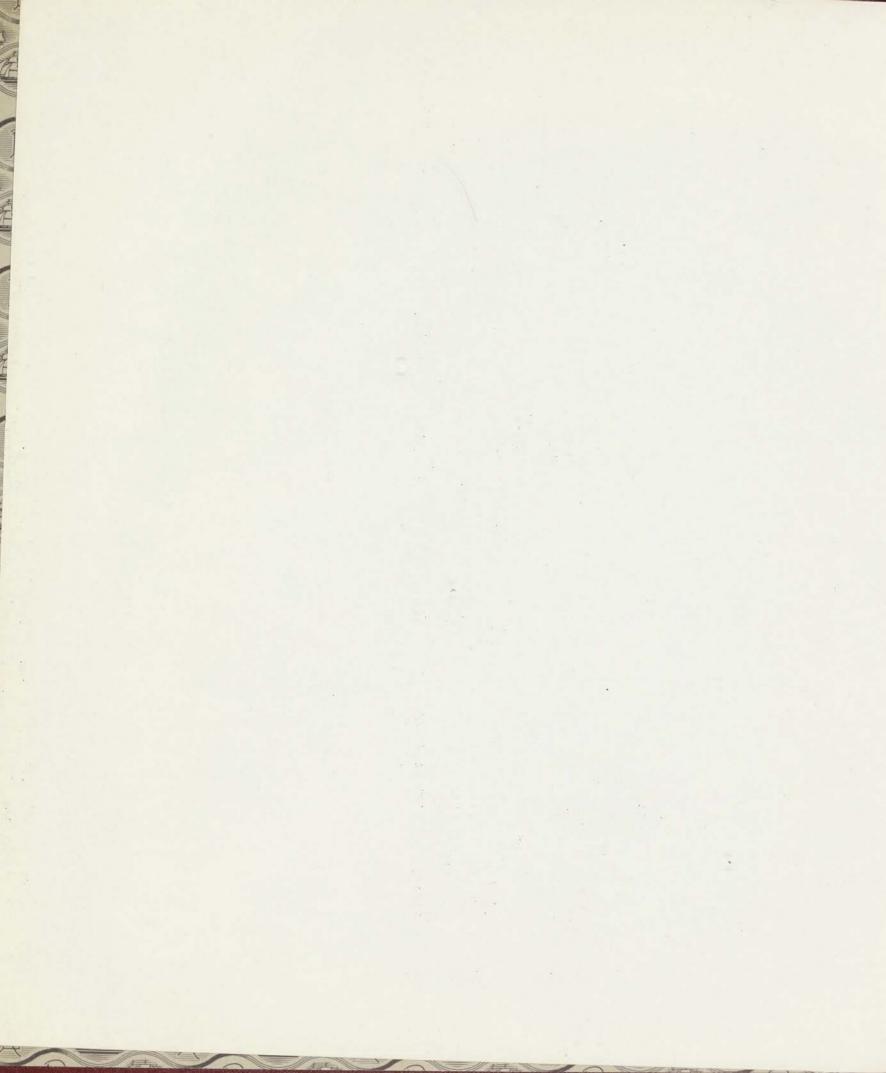


RULES AND REGULATIONS FOR THE CONSTRUCTION AND CLASSIFICATION OF STEEL SHIPS

1972







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REGISTER BOOKS AND OTHER PUBLICATIONS ISSUED BY THE COMMITTEE OF LLOYD'S REGISTER OF SHIPPING

Chapter

LLOYD'S REGISTER BOOK (The Register of Ships and List of Shipowners are issued annually in July and August respectively; the Appendix in January.)

The Register of Ships (in two volumes A-L and M-Z) contains the names, classes and general information concerning the ships classed by Lloyd's Register of Shipping (including the British Corporation Register); also particulars of all known ocean-going merchant ships in the world, of 100 tons gross and upwards.

The second volume (M-Z) also contains floating docks, liquefied gas carriers, ships carrying refrigerated cargo, refrigerated cargo containers, refrigerated stores and container terminals classed with Lloyd's Register and off-shore drilling rigs, as well as lists of changes of ships' names and compound names.

The Register is kept up to date by means of cumulative monthly Supplements containing the latest survey records for all classed ships, and changes of name, ownership, flag, tonnage, &c., for all ships, whether classed or not. Each Supplement is accompanied by particulars of new entries to the Register-that is, new ships and ships of which the names have been changed.

A Weekly List of Alterations in the Register of Ships is also published.

List of Shipowners contains a list of owners and managers of the ships recorded in the Register with their fleets.

The Appendix contains lists of shipbuilders with existing ships they have built; marine enginebuilders and boilermakers; dry and wet docks; telegraphic addresses and codes used by shirping firms; marine insurance companies.

Statistical Tables are issued gratis to Subscribers to the Register Book

REGISTER OF YACHTS Published annually in April, this volume contains in addition to detailed information relating to yachts classed by the Society, the names, dimensions, etc., of other British and overseas yachts, whose particulars are known; a list of one-design and restricted classes; national authorities and list of sail numbers of certain classes of racing yachts*; geographical list of yacht clubs; list and particulars of yacht and sailing clubs with the names of officers; index of signal letters; late names of yachts; names and addresses of yacht builders and designers; list of owners with their addresses, clubs and the names of their yachts.

*LIST OF NATIONAL AUTHORITIES AND SAIL NUMBERS OF RACING YACHTS (as published in the Register of Yachts) may be purchased separately.

THE FLAG BOOKLET (1971 edition). A comprehensive record, in full colour, of yacht club burgees and defaced ensigns as well as the distinguishing flags of yachtsmen.

VACHT RILLES

Vol. I:-WOOD AND COMPOSITE YACHTS (Sailing, Auxiliary, and Full Power)
Vol. II:—STEEL YACHTS Vol. III:—INTERNATIONAL RATING CLASSES PROVISIONAL RULES FOR THE CONSTRUCTION OF REINFORCED PLASTIC YACHTS GUIDE TO MACHINERY AND ELECTRICAL EQUIPMENT IN YACHTS

REGISTER OF AMERICAN YACHTS

This Register is published annually in May from the Society's New York Office. Copies may also be obtained on application to the Manager, Lloyd's Register Printing House, Manor Royal, Crawley, Sussex, England.

This book contains the names, dimensions, and full particulars of the yachts of the United States and Canada, so far as they are ascertainable; reproductions in colour of the burgees of yacht clubs and the private signals of yachtsmen; a list of yacht clubs with the names of their officers; an index of signal letters; late names of yachts; and a list of yacht owners of the United States and Canada, with their addresses, clubs and Yachts.

Also issued separately:-

Club Burgees and Private Signals (in colour).

RULES AND REGULATIONS FOR THE CONSTRUCTION AND CLASSIFICATION OF STEEL SHIPS, which contain the following:-REGULATIONS

General Regulations of Lloyd's Register of Shipping. Classification Regulations. В C Periodical Survey Regulations. CONSTRUCTION RULES D Steel Ships. Pumping and Piping. E Fire Protection, Detection and Extinction. Conditions for Survey of Machinery during Construction. H Main and Auxiliary Engines and Associated Machinery Components. Boilers and other Pressure Vessels. K Spare Gear for Steam and Oil Engine Machinery Installa-Control Engineering Equipment. Electrical Equipment and Electric Propelling Machinery. Refrigerated Cargo Installations. Materials for Ship Construction. Materials for Boiler, Pressure Vessel and Machinery Construction. Appendices giving lists of Approved Manufacturers of Materials and Proving Establishments. Provisional Rules and Guidance Notes: (A) Methane Gas as Fuel for the Propulsion of

Methane Tankers.

(B) Plastic Pipes.

Classification of Nuclear Ships. (c)

Metal Pipes for Water Services. (D)

(E) Torsional Vibration Characteristics of Main and Auxiliary Oil Engines.

Classification of Floating Docks.

Propeller-Hull Clearances. (G)

Repairs by Welding to Steel Castings for Crank Shafts. (H)

Classification of Tankers for the Carriage of Liquid Chemicals in Bulk.

EXTRACTS FROM THE RULES:

B, C, D, P (including Appendices) and R (1)

B, C, E, F, G, H, J, K, L, Q (including Appendices) and R (A, B, D, E, G, H and J)

E, G, H, K, L, Q (including Appendices) and R (A, B, D, E, G, H and J)

No. 5 J, Q (including Appendices) and R (A and н)

No. 6

No. 7 L and M

No. 8 N (and Frozen Meat Stores)

No. 9 P, Q (including Appendices) and R (H)

RULES FOR STEEL TRAWLERS

RULES FOR INLAND WATERWAYS VESSELS

GEOMETRIC PROPERTIES OF ROLLED SECTIONS AND BUILT GIRDERS

Volume I British and U.S.A. Sections Volume II Metric Sections Volume III Japanese Sections

A series of curves giving section moduli and moments of inertia of a wide range of sections used in shipbuilding, in association with varying thicknesses of plating. The areas of sections (without plating) are also given.

FREIGHT CONTAINER CERTIFICATION SCHEME

APPROVED ELECTRODES FOR WELDING IN HULL CON-STRUCTION

LIST OF APPROVED FUSES

LIST OF TYPE TESTED CIRCUIT-BREAKERS

CARGO HANDLING GEAR CODE

PROVISIONAL RULES FOR THE APPLICATION OF GLASS REINFORCED PLASTICS TO FISHING CRAFT

GUIDANCE NOTES AND REQUIREMENTS FOR THE CLASSI-FICATION OF AIR CUSHION VEHICLES

LIST OF TYPE APPROVED CONTROL AND ELECTRICAL **EQUIPMENT**

A

LLOYD'S REGISTER OF SHIPPING



RULES AND REGULATIONS FOR THE CONSTRUCTION AND CLASSIFICATION OF STEEL SHIPS

1972

71 FENCHURCH STREET, LONDON, EC3M 4BS

Telegraphic { Inland: Committee, London, Telex Address { Overseas: Committee, London, E.C.3

Telephone: 01-709 9166 Telex No.: 888379

CHANGES EMBODIED IN PRESENT EDITION OF THE RULES

The following additions and amendments have been adopted by the Committee since the previous (1971) edition of the Rules:-

Chapter B

CLASSIFICATION REGULATIONS

A Note has been added under the Chapter heading.

Classification

Section 1. Paras. 101, 103 and 114 have been amended. New paragraphs (115 to 119) have been added.

Equipment

Section 2. A new paragraph (203) has been added.

Chapter C

PERIODICAL SURVEY REGULATIONS

A Note has been added under the Chapter heading.

Dredgers, Hopper Dredgers, Sand Carriers, Hopper Barges and Reclamation Craft

Section 5. This new section has been added.

General Requirements-Machinery

Section 6. Para. 602. The sub-paragraph headed Air Receivers has been amended. The final sub-paragraph has been amended.

Steam Pipes

Section 11. Paras. 1102, 1103 and 1105 have been amended.

Classification of Ships not built under Survey

Section 13. Para. 1305. The fourth item has been amended and the penultimate item has been added,

Chapter D

STEEL SHIPS

Deck Plating

Section 4. Para. 410 has been revised.

Paras. 411 and 422 have been amended.

Table D 4.3 has been revised.

Shell Plating

Section 5. Paras, 512 and 513 have been amended.

Longitudinal Framing

Section 6. Para. 616 has been amended.

Double Bottoms

Section 9. Para. 929 has been amended.

Superstructures and Deckhouses

Section 17. Para. 1701. The definition of "L" has been amended.

Table D 17.1. The first column in respect of the last two items has been amended and a footnote has been added.

Table D 17.2 has been amended.

Paras. 1708 and 1710 have been amended.

Watertight Bulkheads

Section 18. Para. 1824 has been amended.

Peak, Deep and Topside Tanks

Section 19. Paras. 1903, 1917 and 1928 have been amended.

Steering Gear

Section 23. Paras. 2311 and 2315 have been amended.

Strengthening for Navigation in Ice (General Service)

Section 24. The heading has been amended as above and an introduction has been added. Para. 2401. The definition of "shp" has been amended.

> Strengthening for Navigation in Ice (Northern Baltic Service)

Section 24A. This new section has been added.

Hatchways and Deck Openings

Section 26. A Note has been added under the section heading.

Para, 2601. The definitions of "h" have been amended.

Bulwarks, Freeing Ports, Scuppers and Sanitary Discharges and Side Scuttles

Section 28. Para. 2818 has been amended.

Welding

Section 32. Para. 3203 has been amended.

Equipment

Section 34. Para. 3403. The definition of "h" has been amended.

Para, 3404 has been amended,

Table D 34.1. The note at the foot of the column headed "Towline" has been amended. Notes 1 and 3 to the Table have been amended and a new Note (4) has been added.

OIL TANKERS

General

Section 40. Paras. 4008 and 4009 have been revised.
Para. 4010 has been amended.

Longitudinal Strength

Section 41. Paras. 4102 to 4107 have been revised.

Oiltight and Non-Oiltight Bulkheads

Section 50. Para. 5001. The definitions of "s" and "h" have been amended.

Paras. 5002, 5004, 5006 and 5007 have been amended.

A new paragraph (5008) has been added.

Para. 5023 has been amended.

APPLICATION OF HIGHER TENSILE STEEL

Section 65. This section has been completely revised.

REQUIREMENTS FOR THE CARRIAGE OF LIQUEFIED GASES

General

Section 70. Para. 7004 has been revised.

Carriage at a Pressure of 0,70 kg/cm2 (10 lb/in2) Gauge or less

Section 71. Paras. 7104 and 7105 have been amended.

DREDGERS, HOPPER DREDGERS, SAND CARRIERS, HOPPER BARGES AND RECLAMATION CRAFT

Section 80 to 90. These new sections have been added.

Chapter E

PUMPING AND PIPING

Plans

Section 1. Para. 101. The fourth item has been amended.

Bilge and Ballast

Section 2. Para. 270 has been amended.

Oil Fuel and Cargo Oils having a Flash Point of 60°C (140°F) or above (Closed Cup Test)

Section 3. The heading has been amended as above.
Paras. 302 and 345 have been amended.

Pressure Pipes

Section 5. Para. 523 (b). The formula has been amended.

Lubricating Oil Systems

Section 9. A new paragraph (903) has been added.

Petroleum and other Liquid Cargoes having a Flash Point below 60 °C (140 °F) (Closed Cup Test)

Section 11. The heading has been amended as above.

Chapter F

FIRE PROTECTION, DETECTION AND EXTINCTION

Requirements for Cargo Ships

Section 5. Para. 516 has been amended.

General Requirements

Section 1. A heading has been added to this section as above.

Para, 108 has been amended.

Certification of Batch and Line Produced Machinery

Section 2. This is a new section.

Chapter H MAIN AND AUXILIARY ENGINES AND ASSOCIATED MACHINERY COMPONENTS Reduction Gearing for Propelling and Auxiliary Engines

Section 3. Para. 301 has been amended. Para. 307 has been revised.

> Strengthening for Navigation in Ice (General Service)

Section 5. The heading has been amended as above.
Para, 501 has been amended.

Strengthening for Navigation in Ice

(Northern Baltic Service)

Section 5A. This new section has been added.

General Requirements for Oil Engines and Starting Air Compressors

Section 6. Paras. 603, 613, 614 and 618 have been amended. A new paragraph (619) has been added.

General Requirements for Steam Turbines

Section 8. This section has been revised and the heading amended as above.

General Requirements for Gas Turbines

Section 9. This new section has been added.

Chapter M ELECTRICAL EQUIPMENT AND ELECTRIC PROPELLING MACHINERY

Control Gear

Section 7. Para. 706 has been amended.

Special Requirements for Oil Tankers and Ships intended for the Carriage in bulk of Liquid Cargoes having a Flash
Point below 60 °C (140 °F) (Closed Cup Test)

Section 16. The heading has been amended as above.

Chapter P

MATERIALS FOR SHIP CONSTRUCTION

Mild Steel for Hull Structures

Section 2. Table P 2.2. Note 6 has been amended.

Steel Anchors

Section 7. Paras. 704 and 705 have been amended.

Chain Cables and Steering Chains

Section 8. Paras. 807 (b), 809 and 810 have been amended.

Table P 8.1 has been amended.

Table P 8.3 (Metric Units) has been revised.

Steel Wire Ropes for Standing Rigging, Towlines and Mooring Ropes

Section 9. Para. 902 has been amended.

Table P 9.1 has been amended.

Approval of Electrodes and Combinations of Consumables for Welding in Hull Construction Section 11. This section has been revised and the heading amended as above.

Chapter Q MATERIALS FOR BOILER, PRESSURE VESSEL AND MACHINERY CONSTRUCTION Steel Castings

Section 5. Paras. 507 and 521 have been amended.

Chapter R

PROVISIONAL RULES AND GUIDANCE NOTES

R(J)—Provisional Rules for the Classification of Tankers intended for the Carriage of Liquid Chemicals in bulk These provisional Rules have been added.

A number of alterations of an editorial or minor nature have also been made,

J. HUXSTER, Secretary

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Chapter A

GENERAL REGULATIONS OF LLOYD'S REGISTER OF SHIPPING

Section 1

This Society, founded in 1760 and reconstituted in 1834, was established for the purpose of obtaining for the use of Merchants, Shipowners, and Underwriters, a faithful and accurate Classification of Mercantile Shipping. The Society continues to fulfil that purpose; and in addition approves design, surveys and issues reports on hovercraft, non-mercantile shipping, on amphibious and land installations, and on machinery, apparatus, materials and mass production methods of all kinds, for the purpose of testing their compliance with plans and specifications, or their fitness for particular requirements. This Chapter contains the General Regulations which have been from time to time adopted for the government of the Society.

Section 2

The superintendence of the affairs of the Society to be under the direction of the General Committee composed of

- 5 members nominated by the Chamber of Shipping of the United Kingdom as well as the Chamber's President and Vice-President ex officio.
- 13 members nominated by the London General Shipowners' Society as well as that Society's Chairman and Deputy-Chairman ex officio.
- 9 members nominated by the Committee of Lloyd's as well as the Chairman and a Deputy-Chairman of Lloyd's ex officio.
- 4 members nominated by the Institute of London Underwriters as well as the Institute's Chairman and Deputy-Chairman ex officio.
- 5 members nominated by the Shipbuilders and Repairers National Association.
- 3 members nominated by the National Association of Marine Enginebuilders.
- 40 members nominated to represent United Kingdom outports including the representation of the Liverpool and Scottish Committees.
 - All nominations to be subject to confirmation by the General Committee.
- 40 other members specially elected by the General Committee to include up to 12 International Shipowners and 5 Industrial Services representatives together with past Chairman and Deputy-Chairmen of the General Committee and Chairmen of National Committees appointed under Section 5.

The General Committee are further empowered to elect as Honorary Members of the General Committee such persons of distinction and eminence as the General Committee shall from time to time think fit.

Section 3

The General Committee reserve the right of varying the representation or ex officio membership on the General Committee of Shipowners and Underwriters, and of varying or withdrawing the representation or ex officio membership of the General Committee of all other bodies entitled to nominate members specially or ex officio.

Section 4

- 1. All members of the General Committee who have been nominated or who are members ex officio shall retire annually and may be renominated by their respective nominating bodies or may become ex officio members for the ensuing year.
- 2. All members elected by the General Committee are to retire at the end of four years, and are to be eligible for re-election.

Section 5

- 1. The General Committee to appoint Sub-Committees of Classification, to be so regulated that appointed Members of the General Committee may, in rotation, take their turn of duty thereon throughout the year.
- 2. The General Committee may also appoint a National Committee in any country where it appears that such a Committee could form a useful liaison between the Society and the maritime and commercial communities in that country. National Committees may consist of or include persons who are not members of the General Committee.

Section 6

The Committee to appoint from their own body a Chairman to hold office for such period as they shall determine and two Deputy-Chairman who shall be elected annually; one Deputy-Chairman being designated Deputy-Chairman and Treasurer and the other Deputy-Chairman and Chairman of the Sub-Committees of Classification.

Section 7

The Servants of the Society to be appointed by and be under the direction of the General Committee.

Section 8

Special meetings to be convened by order of the Chairman, or one of the Deputy-Chairmen, or on the requisition of any three Members.

Section 9

All elections and appointments to be made by ballot, if demanded, excepting when, in the election of Chairman or one of the Deputy-Chairmen, only one person is nominated for each office.

Section 10

- 1. The General Committee to be empowered:—
- (a) At any time, and from time to time, to delegate all or any of their powers to an Executive Board consisting of such members of the General Committee and to be selected in such manner as the General Committee may think fit, and to make Regulations for the meetings, proceedings and other activities of such Executive Board, and
- (b) to make such By-Laws for their own government and proceedings and for representation from the outports as they may deem requisite; but no new Rule or By-Law to be introduced or any Rule or By-Law altered, without special notice being given for that purpose at the meeting of the General Committee next preceding that at which such motion is intended to be made; such notice to be inserted in the summons convening the meeting.

Section 11

No new Rule, or alteration in any existing Rule materially affecting the classification of ships, to be applied compulsorily to ships of which the plans have been submitted and approved before the expiration of six months after the date when the change has been adopted.

Section 12

A Register Book to be printed annually for the use of Subscribers, containing the names of the ships with other useful information, and the character assigned, where the ships are classed by the Society; also the names, etc., of ships of 100 gross registered tons and upwards which are not classed with the Society.

The terms of subscription to be such annual sum or sums as may from time to time be determined by the General Committee.

Section 13

TECHNICAL COMMITTEE

1. The Technical Committee to be constituted as follows:-

Ex-officio—	Ship- owners	Under- writers	Ship- builders	Engineers	Others	TOTAL
The Chairman of Lloyd's Register	-	1	-	-	-	1
The Deputy-Chairman and Chairman of the Sub-Com-						
mittees of Classification of Lloyd's Register	1	-			-	1
The Deputy-Chairman and Treasurer of Lloyd's Register	1	-	-	- 4	-	1
Nominated by—						
The General Committee of Lloyd's Register	5	3	2	2	22	12
The Royal Institution of Naval Architects	-	_	1	1		2
The North-East Coast Institution of Engineers and Ship-						
builders		-	1	1	_	2
The Institution of Engineers and Shipbuilders in Scotland		-	1	1	-	2
The Shipbuilders and Repairers National Association	-	-	5	-	2	7
The National Association of Marine Enginebuilders	-	_		3	-	3
The Institute of Marine Engineers	-	-		2	_	2
The British Internal Combustion Engine Manufacturers'						
Association	_	-	120	1	-	1
The Society of Consulting Marine Engineers and Ship						
Surveyors	-	-	_	1	+ (1)	1
The Iron and Steel Institute	-	_	-	-	1	1
The British Steel Corporation	-	-	-	_	1	1
The British Independent Steel Producers' Association	1-1	-	-	-	1	1
The Honourable Company of Master Mariners	-	-	-	-	1	1
The Institution of Electrical Engineers	-	-	+	-	1	1
The British Electrical and Allied Manufacturers' Asso-						
ciation, Ltd		_	=		1	1
The Technical Committee	3	_	2	2	2	7
The Technical Committee (from other countries abroad)	-	-	-	-	8	8
	10	4	12	14	16	56

The above nominations to be subject to confirmation by the General Committee.

In addition to the foregoing:-

- (a) Each National Committee appointed under Section 5, may appoint a representative to attend meetings of the Technical Committee.
- (b) Further persons may, with the consent of the General Committee, be co-opted to serve on the Technical Committee.
- 2. The function of the Technical Committee is to consider any technical problems connected with the Society's business and any proposed alterations in the existing Rules, or to frame new Rules, for the classification, survey and building of ships (hull and machinery).

- 3. The term of office of all Members to be four years, one-fourth retiring each year, the Members so retiring to be eligible for renomination for a second term. Unless specially so authorized by the General Committee, no Member, other than Chairmen and/or Vice-Chairmen, who has served for two periods of four years to be eligible for renomination for a third term until after the expiration of at least one year. In the event of any vacancy occurring before the expiration of a term of four years a representative to be nominated to fill the vacancy for the unexpired portion of the term.
- Technical Directors and Superintendents nominated by the Technical Committee, or those who are partners in firms, or directors or managers of joint stock companies, or of similar status, to be eligible for membership.
- 5. The Technical Committee to appoint from their own body, biennially, a Chairman, or two alternative Chairmen, who must be a Member, or Members, of the General Committee, and, if desired, a Vice-Chairman or two alternative Vice-Chairmen, who need not be Members of the General Committee. The same Members not to be eligible to hold office for more than four years in succession, unless on the occasion of the third election a ballot—to be taken whether there be any other candidates or not—shows a majority in their favour of at least three-fourths of the Members present. The appointment of all Chairmen and Vice-Chairmen to be confirmed by the General Committee.
- 6. Meetings of the Technical Committee to be convened as often and at such times and places as may appear necessary, but there shall be at least two meetings in each year.
- 7. Members desiring to propose alterations in, or additions to, the Rules for the classification, survey or building of ships (hull and machinery) shall give notice of all such proposals in writing to the Secretary.

Every meeting to be convened by notice from the Secretary, if possible one month before the date of meeting; and the Secretary to send to each Member an agenda paper as soon as possible thereafter.

- 8. Any proposals of the Technical Committee involving any amendment of, or addition to, the Rules for the classification, survey or building of ships (hull and machinery) to be reported to the General Committee, who will refer them to a special meeting of the General Committee, as required by Section 10(b) of this Chapter.
 - 9. The Technical Committee to be empowered:-
 - (i) to draw up, if they so desire, By-Laws for governing procedure at Meetings;
 - (ii) to appoint Panels of the Committee;
 - (iii) to co-opt to the main Committee, or to such Panels, representatives of any organization or industry or private individuals for the purpose of considering any particular problem.
- 10. The General Committee reserve to themselves the right of varying, adding to, or rescinding, at their discretion, any or all the Regulations in this Section including the representation of the bodies mentioned in Para. 1.

Section 14

All reports of survey are to be made by the Surveyors according to the form prescribed, and submitted for the consideration of the General Committee, or of the Sub-Committees of Classification, but the character assigned by the latter to be subject to confirmation by the General Committee or by the Chairman acting on behalf of the General Committee.

Section 15

The reports of the Surveyors (and all documents and proceedings relating to the classification of ships) are to be carefully preserved and shall, subject to the approval, in his absolute discretion, of the Chairman or one of the Deputy-Chairmen, be open to the inspection of the Owner and of any other person authorized in writing by the Owner.

Copies of reports will, subject to the approval of one of the Chairmen as indicated above, be supplied to Owners, or their representatives, on application.

Section 16

The Surveyors to the Society are not to be permitted (without the especial sanction of the General Committee) to receive any fee, gratuity, or reward whatsoever, for their own use or benefit, for any service performed by them in their capacity of Surveyors to this Society, on pain of immediate dismissal.

Section 17

The Committees of the Society use their best endeavours to ensure that the functions of the Society are properly executed, but it is to be understood that neither the Society nor any Member of any of its Committees, nor any of its Officers, Servants or Surveyors is under any circumstances whatever to be held responsible or liable for any inaccuracy in any report or certificate issued by the Society or its Surveyors, or in any entry in the Register Book or other publication of the Society, or for any act or omission, default or negligence of any of its Committees or any Member thereof, or of the Surveyors, or other Officers, Servants or Agents of the Society.

Section 18

The funds and accounts to be under the authority and control of the General Committee.

Section 19

Fees are chargeable for all surveys held by the Society's Surveyors at ports in the United Kingdom in accordance with established scales.

For all surveys held at ports abroad fees will be chargeable according to the nature and extent of the services rendered.

Travelling expenses incurred by the Surveyors in connection with the above services are also chargeable.

Section 20

The class of a ship is liable to be withheld, or, if already granted, may be withdrawn from the Register Book, in the case of non-payment of any fees or expenses chargeable on account of such ship.

21st May, 1970

Chapter B

CLASSIFICATION REGULATIONS

Note. Attention is drawn to the special requirements for dredgers, hopper dredgers, sand carriers, hopper barges and reclamation craft in B 1 and B 2.

Section 1

CLASSIFICATION

General

101 Steel ships built in accordance with the Society's Rules and Regulations, or with alternative arrangements equivalent thereto (see B 501), will be assigned a class in the Register Book and will continue to be classed so long as they are found, upon examination at the prescribed annual and other periodical surveys, to be maintained in a fit and efficient condition and in accordance with the requirements of the Rules.

The Committee, in addition to requiring compliance with the Society's Rules, may require to be satisfied that very small ships, or ships of special type are suitable for the geographical limits of service contemplated.

Classification will be conditional upon compliance with the Society's requirements in respect of both hull and machinery (i.e., main and auxiliary engines including torsional vibration characteristics, boilers, essential appliances, pumping arrangements and electrical equipment).

The Rules are framed on the understanding that ships will be properly loaded and handled; they do not, unless stated in the class notation, provide for special distributions or concentrations of loading. The Committee may also require additional strengthening to be fitted in any ship which, in their opinion, may be subjected to severe stresses due to particular features in her design or when it is desired to make provision for exceptional loaded or ballasted conditions. In these cases particulars are to be submitted for consideration.

The Committee cannot assume responsibility for stability, trim, hull vibration or other technical characteristics not covered by the Rules, but they are willing to advise on these matters. They are also willing to act in respect of national and international statutory safety and other requirements for passenger and cargo ships governing arrangements not covered by the Society's Rules.

In the cases of dredgers, hopper dredgers, sand carriers, hopper barges or reclamation craft, each ship proceeding to sea is to comply with the draught requirements of the National Authority and is to have on board sufficient stability data to enable it to be properly loaded and handled or, where appropriate, for the ship to be properly towed. In the case of an unmanned ship under tow, the data is to be made available to the tugmaster. This data is to take full account of any special distribution or concentration of loading for which the particular ship may be designed (see also D 8005, D 8008 (j) and D 9002).

Character of Classification and Class Notations

- 102 Class 100A1. This class will be assigned to sea-going ships built in accordance with the Society's Rules and Regulations for the draught required.
- 103 Class 100A1 oil tanker. This class will be assigned to sea-going tankers intended to carry oil in bulk and built in accordance with the Society's Rules and Regulations for the draught required.

Where the scantlings and arrangements have been approved by the Committee for the carriage of oil having a flash point of 60°C (140°F) or above (closed cup test) or other liquid cargoes in bulk, the class notation affixed to the character will be suitably modified to show the nature of the cargo.

104 Class 100Al liquefied gas carrier, type of gas(es) in independent tanks, maximum vapour pressure, minimum temperature and where necessary maximum temperature (to be specified). This class will be assigned to sea-going ships specially designed for the carriage of liquefied petroleum, natural or other gases and built in accordance with the Society's Rules and Regulations for the draught required.

- 105 Class 100A1 ore carrier. This class will be assigned to sea-going ships specially designed for the carriage of ore and built in accordance with the Society's Rules and Regulations for the draught required.
- 106 Class 100A1 trawler, 100A1 stern trawler, 100A1 fishing vessel. These classes will be assigned to ships built in accordance with the appropriate Rules and Regulations for the Construction of Steel Trawlers.
- 107 Class 100A1 tug. This class will be assigned to all sea-going tugs built in accordance with the Society's Rules and Regulations for such ships.
- 108 Class 100A1 icebreaker. This class will be assigned to sea-going ships specially designed for icebreaking duties, and built in accordance with those Sections of the Society's Rules and Regulations appropriate to such ships, and other special requirements as may be approved by the Committee for the proposed service.
- 109 Class 100A1 for restricted service or for special purposes. This class will be assigned to sea-going ships intended to operate within specific limits or for special purposes and built in accordance with the Society's Regulations and the scantlings, arrangements and equipment specially approved by the Committee for such ships. The class notation affixed to the character in the Register Book will indicate the geographical limits of the service or the particular purpose for which the class is assigned.
- 110 Class A1 for restricted service. This class will be assigned to ships intended to trade only within specially sheltered waters, such as harbours, rivers or estuaries, provided the scantlings, arrangements and equipment are approved by the Committee as suitable for such service. The class notation affixed to the character will indicate the geographical limits for which the ship has been approved.
- 111 Special cargoes. When the scantlings and arrangements have been approved for cargoes of a special nature an appropriate class notation will be entered in the Register Book.
- 112 Special features. When a special feature in the design or construction of a ship or its machinery has been approved, an appropriate class notation may be entered in the Register Book.
- 113 Corrosion control. Where an approved method of corrosion control is fitted and an appropriate reduction in scantlings has been permitted, the notation (cc) will be entered in the Register Book.
- 114 Strengthening for Navigation in Ice. Where an ice class notation is desired, additional strengthening is to be fitted in accordance with the requirements given in the Rules. Details of the requirements are given in the Rules for the following classes of ice strengthening:—
 - (a) For general service:
 - Ice Class 1* strengthening is for ships intended to navigate in extreme ice conditions.
 - Ice Class 1 strengthening is for ships intended to navigate in severe ice conditions.
 - Ice Class 2 strengthening is for ships intended to navigate in intermediate ice conditions.
 - Ice Class 3 strengthening is for ships intended to navigate in light ice conditions.
 - (b) Primarily for trading in the northern Baltic in winter time:
 - Ice Class IA Super strengthening is for ships intended to navigate in extreme ice conditions.
 - Ice Class IA strengthening is for ships intended to navigate in severe ice conditions.
 - Ice Class IB strengthening is for ships intended to navigate in medium ice conditions.
 - Ice Class IC strengthening is for ships intended to navigate in light ice conditions.

These requirements for classes are equivalent to those for the corresponding notations in Annex I of the "Finnish-Swedish Ice Class Rules 1971".

It is the responsibility of the Owner to determine which notation is most suitable for his requirements.

SPECIAL REQUIREMENTS FOR DREDGERS, HOPPER DREDGERS, SAND CARRIERS, HOPPER BARGES AND RECLAMATION CRAFT

Definitions

115 Dredger. A ship designed to operate wholly or generally for the purpose of raising mud, silt, gravel, clay or similar substances, general rubbish or ore, minerals, etc., from the bed of the sea, rivers, lakes, canals, or harbours, etc.

Reclamation Craft. Reclamation ships, etc., which work in a manner similar to suction dredgers but draw their spoil from hopper barges (or floating pipe lines connected to a dredger) and discharge it ashore.

Hopper. A hold or other space designed to carry dredged spoil and also arranged to enable such spoil to be discharged through doors or valves in the bottom of the ship.

Spaces arranged to be unloaded by means of conveyor belts, suction pipes or similar gear are not to be regarded as hoppers unless adequate bottom doors or valves are also fitted.

Hopper Dredger. A dredger constructed such that the dredged material may be stored or transported in one or more hoppers within the ship.

Sand Carrier. A dredger, other than a hopper dredger, constructed such that the dredged material, which need not be restricted to sand, may be stored or transported in suitably designed holds or similar spaces within the ship.

Note:—Diamond dredgers and similar ships with onboard processing plant will not normally be regarded as sand carriers unless the weight of ore and spoil on board during processing operations exceeds 25 per cent of the ship's light-weight displacement.

Hopper Barge. A ship which need not be self-propelled designed to carry bulk cargo in hoppers within the ship. Fetch. The extent of clear water across which a wind has blown before reaching the ship.

Clear water. Water having sufficient depth to permit the normal development of wind generated waves,

Sheltered water. Water where the fetch is six nautical miles or less.

Reasonable weather. For the purpose of assessing scantlings in these Rules, reasonable weather is assumed to exclude winds exceeding Beaufort force 6 associated with sea states resulting in green water being frequently taken on board the ship's deck. However, it is realized that this is largely a matter of judgment and good seamanship and can vary for particular ships.

Character of Classification and Class Notation

116 Class 100Al dredger

Class 100A1 hopper dredger

Class 100A1 sand carrier

Class 100A1 hopper barge

Class 100A1 reclamation craft.

These classes will be assigned to ships built in accordance with the Society's Rules and Regulations for the draughts required, and which are intended to make sea-going voyages either as part of their work or while transferring from one work area to another as part of their normal operations.

Bucket dredgers will not be assigned this character of classification.

Sand carriers will not normally be assigned this character of classification unless spoil spaces are provided with adequate hatch covers.

117 Class 100A1 dredger, restricted service

Class 100A1 hopper dredger, restricted service

Class 100A1 sand carrier, restricted service

Class 100A1 hopper barge, restricted service

Class 100A1 reclamation craft, restricted service.

These classes will be assigned to ships built in accordance with the Society's Rules and Regulations and having the reduced scantlings permitted by the Rules for the draughts required and which are intended to operate in estuaries, harbours and/or adjacent waters; only proceeding outside sheltered water for short distances (generally less than 15 nautical miles) and in reasonable weather. Loading conditions and any other preparations required to permit the ship to undertake a sea-going voyage, either from port of building to service area, or from one service area to another, are to be in accordance with instructions agreed to by the Society at the time of plan approval.

The above limitations, applicable to a ship classed "restricted service", will also appear in the key to the Register Book.

118 Class A1 dredger, protected waters service

Class A1 hopper dredger, protected waters service

Class A1 sand carrier, protected waters service

Class A1 hopper barge, protected waters service

Class A1 reclamation craft, protected waters service.

These classes will be assigned to ships built in accordance with the Society's Rules and Regulations for the draughts required, and which are intended to operate only within protected waters such as harbours, rivers, small lakes and sheltered estuaries.

The above limitations, applicable to a ship classed "protected waters service", will also appear in the key to the Register Book.

Descriptive Note

119 An appropriate descriptive note will be entered in Column 6 of the Register Book indicating the type of dredger, sand carrier or hopper barge, e.g.:—

Trailing Suction Dredger
Cutter Suction Dredger
Bucket Dredger
Grab Dredger
Dipper Dredger
Self-Discharging Sand Dredger.

Section 2

EQUIPMENT

- 201 The figure 1 in the character of classification assigned to a ship indicates that her equipment of anchors, chain cables and hawsers is in good and efficient condition and in the cases of ships not classed for a special or restricted service, in accordance with the requirements of the Rules. In the case of ships classed for a special or restricted service, the figure 1 indicates that the equipment has been approved by the Committee as suitable for the particular service.
- 202 When the equipment of a ship is not supplied or maintained in accordance with the requirements of the Rules but is considered by the Committee to be acceptable for the particular service, the Committee may agree to the figure 1 being omitted and a line inserted after the character, thus, 100A—. In cases where the equipment is found to be seriously deficient in quality or quantity, the class of the ship will be liable to be withheld from the Register Book. Special consideration will be given to ships intended to be classed for which, by reason of their particular purpose or service, normal equipment may be unnecessary. In such cases the figure 1 may be omitted from the character of classification, viz., 100A.

Special requirements for Dredgers, Hopper Dredgers, Sand Carriers, Hopper Barges and Reclamation Craft

203 The figure 1 in the character of classification assigned to a ship indicates that her equipment of anchors, chain cables and hawsers is in good and efficient condition and in accordance with the requirements of the Rules. In the case of ships classed for restricted or protected waters service, the figure 1 indicates that the anchoring and mooring equipment has been approved by the Committee as suitable for the particular service.

Section 3

MACHINERY

- 301 (a) The machinery, as defined in B 101, is to be constructed and installed on board ship in accordance with the Society's Rules and Regulations. On satisfactory completion of trials, an appropriate class notation will be assigned in the Register Book, thus, LMC (Lloyd's Machinery Certificate).
- (b) Where arrangements are such that essential machinery can be operated by remote and/or automatic control equipment the control equipment is to be arranged, installed and tested in accordance with the Society's Rules and Regulations.
- (c) When arrangements are such that the ship can be operated with the machinery spaces unattended (see Chapter L) a notation "UMS" will be assigned in the Register Book unless the Owner expresses a wish to the contrary. Non-compliance with the relative sections of Chapter L will not affect the LMC notation since the Society's Rules require that the essential machinery can be operated satisfactorily with the control system(s) out of action.

Section 4

MATERIALS

401 The materials used in the construction of hulls and machinery intended for classification, or in the repair of ships already classed, are to be of good quality and free from defects and are to be tested in accordance with the requirements of Chapters P and Q. The steel is to be manufactured by an approved process at works recognized by the Committee. Alternatively, tests to the satisfaction of the Committee will be required to demonstrate the suitability of the steel.

Section 5

EQUIVALENT ARRANGEMENTS

501 Alternative arrangements will be permitted, provided they are considered by the Committee to be equivalent to the Society's requirements.

Section 6

NEW CONSTRUCTION

Submission of Plans

601 When it is intended to build a ship for classification with the Society, constructional plans and particulars of the hull, equipment and machinery (see B 101), as detailed in the Rules, are to be submitted through the local Surveyors for the approval of the Committee before the work is commenced.

Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

Use of Approved Items of Machinery

602 Machinery may incorporate items which have been type tested and approved by the Committee.

Constructional plans and particulars of approved items need not be included in submissions made in accordance with 601.

Novel Forms of Construction

603 Where the proposed construction of any part of the hull or machinery is novel in design, or involves the use of unusual material, or where experience, in the opinion of the Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. A suitable notation will be inserted in the Register Book when the Committee consider this necessary.

Special Survey during Construction

804 New ships intended for classification are to be built under the Society's Special Survey and when classed will be entitled to the distinguishing mark *\mathbb{H}\) inserted before the character in the Register Book, thus: *\mathbb{H}\)100A1.

From the commencement of the work until the completion of the ship, the Surveyors are to examine the materials, workmanship and arrangements. Any items not in accordance with the Rules or the approved plans, or any material, workmanship or arrangement found to be unsatisfactory are to be rectified.

New machinery for ships classed or intended for classification is to be constructed under the Society's Special Survey, and on completion will be entitled to the distinguishing mark # inserted before the machinery class notation in the Register Book, thus: **LMC.

The Special Survey during construction of the machinery shall relate to the period from the commencement of the work until the final test under working conditions. Any items not in accordance with the Rules or the approved plans, or any material, workmanship or arrangement found to be unsatisfactory are to be rectified.

Date of Build

605 The date of completion of the Special Survey during Construction of ships built under the Society's inspection will normally be taken as the date of build to be entered in the Register Book. If the period between launching and completion or commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the Register Book.

When a ship upon completion is not immediately put into commission, but is laid up for a period, the Committee, upon application by the Owner, prior to the ship proceeding to sea, may direct an examination of the ship to be made in drydock by the Society's Surveyors. If, as the result of such survey, the hull and machinery be reported in all respects free from deterioration, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

Section 7

CLASSIFICATION OF SHIPS NOT BUILT UNDER SURVEY

701 The requirements of the Committee for the classification of ships which have not been built under the Society's survey are set forth in C 13.

Section 8

PERIODICAL SURVEYS

Annual Surveys

801 All steel ships are to be surveyed at intervals of approximately one year, in accordance with the requirements set forth in C 1.

Docking Surveys

802 Owners should notify the Society whenever a ship can be examined in drydock or on a slipway. It is desirable that ships should be examined in drydock at intervals of about 12 months; the maximum interval is to be two years, except that where a suitable high resistance paint is applied to the underwater portion of the hull and an approved automatic system of impressed current external cathodic protection is fitted, this maximum interval may be extended to about 2½ years at the discretion of the Committee.

Attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is registered.

This regulation is not applicable to ships operating in fresh water or to certain non-propelled craft; the interval between drydockings for these ships may be greater than is stated above.

The date of the last examination in drydock or on a slipway will be recorded in the Supplement to the Register Book.

Special Surveys

803 All steel ships classed with the Society are also to be subjected to Special Surveys in accordance with the requirements set forth in C 2 to C 9. These surveys become due at 4-yearly intervals, the first 4 years from the date of build or date of Special Survey for Classification, and thereafter 4 years from the date of the previous Special Survey.

Period allowed for completion of Special Surveys

804 When it is inconvenient for Owners to fulfil all the requirements of a Special Survey at its due date, the Committee will be prepared to consider its postponement, either wholly or in part, provided that the Society's Surveyors are afforded an opportunity, about the due date, of assessing the general condition of the hull. For this purpose the Committee will normally call for a general examination of the ship, including drydocking, of sufficient extent to be assured that her condition is satisfactory for the period of grace desired, which is not to exceed 12 months from the due date.

Special Surveys which are commenced prior to their due date are not to extend over a period greater than 12 months, except with the prior approval of the Committee, who will be prepared to consider suitable arrangements for carrying out Special Surveys over an extended period in the case of ships engaged on a regular schedule.

Record of Special Surveys

805 Ships which have satisfactorily passed a Special Survey will have a record entered in the Supplement to the Register Book indicating the date. At each Special Survey of dry cargo ships over 20 years old and tankers over 10 years old at which the prescribed requirements for determining the thickness of the structure will have been complied with, the record "TD" (thickness determination) will be entered. Where a Special Survey is not completely carried out at one time, the date recorded in the Supplement will be the date at which the principal part of the requirements is complied with. Records of Special Survey will not be assigned until the Society's requirements for machinery surveys detailed in 807 or 808 are satisfactorily completed.

Continuous Surveys

806 When, at the request of Owners, it has been agreed by the Committee that the complete survey of the hull may be carried out on the Continuous Survey basis, all compartments of the hull should be opened for survey and testing in rotation with an interval of five years between consecutive examinations of each part.

If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor.

Ships which have satisfactorily completed the cycle will have a record entered in the Supplement to the Register Book indicating the date of completion.

Surveys of Machinery

807 Machinery, as defined in B 101, is to be submitted to the surveys described in C 6 to C 12.

Complete Surveys of machinery become due at 4-yearly intervals, the first one 4 years from the date of build or date of first Classification as recorded in the Register Book, and thereafter 4 years from the date of the previous Complete Survey. Whether or not Complete Surveys are commenced prior to their due date, they are not to extend over a period greater than 12 months without the approval of the Committee. On satisfactory completion of a survey an appropriate

record will be made in the Supplement to the Register Book. When a Complete Survey is not carried out at one time the date recorded in the Supplement will be that by which the major portion of the survey has been held.

If it is found desirable that any part of the machinery should be again examined before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

When it is inconvenient for Owners to fulfil all the requirements of a Complete Survey at its due date, the Committee will be prepared to consider its postponement, either wholly or in part, provided that the Society's Surveyors are afforded an opportunity, about the due date, of assessing the general condition of the machinery. For this purpose the Committee will normally require a general examination to be made of sufficient extent to assure them that the condition of the machinery is satisfactory for the period of grace desired, which is not to exceed 12 months from the due date. This general examination will usually include any item which has not been surveyed for 5 years, together with any item in respect of which the 5-year interval would otherwise be exceeded during the period of postponement.

Continuous Surveys of Machinery

808 When, at the request of Owners, it has been agreed by the Committee that the complete survey of the machinery may be carried out on the Continuous Survey basis, the various items of machinery should be opened for survey in rotation, so far as practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one-fifth of the machinery should be examined each year.

In such cases a record indicating the date of completion of the Continuous Survey cycle will be made in the Supplement to the Register Book.

If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor and the defects are to be made good to his satisfaction.

Upon application by Owners the Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the ship at ports where the Society is not represented or, where practicable, at sea, and a limited confirmatory survey carried out at the next port of call where an Exclusive Surveyor is available. Particulars of the arrangement may be obtained from the Society's Head Office.

Boiler, Steam Pipes and Screw Shaft Surveys

809 Boiler Surveys, examination of Steam Pipes and Screw Shaft Surveys should be carried out as set forth in C 10, C 11 and C 12. On satisfactory completion, appropriate records will be made in the Supplement to the Register Book.

Section 9

REFRIGERATION

- 901 On application from Owners, refrigerated cargo installations which comply with Chapter N of the Rules and are favourably reported on by the Surveyors will be assigned an appropriate class in accordance with N 1. Certificates will be issued and the class notation, together with the particulars of the installation, will be entered in the Supplement.
- 902 The class assigned will be retained provided the installation is found to be in a good and efficient condition at the Periodical, Loading Port and other Surveys set forth in N 8.
- 903 The paragraphs in B 14 regarding Withdrawal of Class and in B 15 regarding Reclassification, apply also to Refrigerated Cargo Installations.

Section 10

REPAIRS AND ALTERATIONS

Repairs

- 1001 All repairs to hull, equipment and machinery which may be required in order that a ship may retain her class are to be carried out under the inspection of, and to the satisfaction of, the Society's Surveyors. When repairs are effected at a port where there is no Surveyor to this Society, the ship is to be surveyed by one of the Society's Surveyors at the earliest opportunity.
- 1002 When at any survey the Surveyors consider repairs to be necessary, either as a result of damage, or of wear and tear, they will communicate their recommendations at once to the Owners, or their representative, and if compliance therewith cannot be arranged, immediate notification will be given by the Surveyors to the Committee.
- 1003 If a ship which is classed with the Society is damaged to such an extent as to necessitate towage outside port limits, it shall be the Owner's responsibility to notify Lloyd's Register at the first practicable opportunity.

Alterations

1004 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery, are to be submitted for approval and such alterations are to be carried out under the inspection of, and to the satisfaction of, the Society's Surveyors.

Section 11

APPEAL FROM SURVEYORS' RECOMMENDATIONS

1101 If the recommendations of the Society's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Committee, who may direct a special examination to be held.

Section 12

NOTICE OF SURVEYS

1201 It is the responsibility of Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time under the supervision of the Society's Surveyors.

It is, however, the normal practice of the Society to give timely notice to Owners when Special Surveys become due, but the non-receipt of such notice, or of notice regarding other surveys, does not absolve Owners from this responsibility.

Section 13

CERTIFICATES

- 1301 When the required reports on completion of the Special Surveys of new ships, or of existing ships submitted for classification, have been received from the Surveyors and approved by the Committee, certificates of first entry of classification, signed by the Chairman, Deputy-Chairman and Treasurer, or Deputy-Chairman and Chairman of the Sub-Committees of Classification, and countersigned by the Secretary, will be issued to Builders or Owners.
- 1302 Certificates of class maintenance in respect of completed periodical surveys of hull and machinery will also be issued to Owners on application.
- 1303 The Society's Surveyors are permitted to issue provisional certificates to enable a ship, classed with the Society, to proceed on her voyage provided that, in their opinion, she is in a fit and efficient condition. Such certificates will embody the Surveyor's recommendations for continuance of class, but in all cases are subject to confirmation by the Committee.

Section 14

WITHDRAWAL OF CLASS

Owners' Requests

1401 When the class of a ship, for which the Regulations as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Committee in consequence of a request from the Owners, the notation "Class withdrawn at Owners' request" (with date) will be made in the Supplement and the notation "LR class withdrawn—Owners' request" (with date) will be made in the next reprint of the Register Book. After one year the notation will be altered to "Classed LR until" (with date).

Non-Compliance with the Regulations

1402 When the Regulations as regards surveys on the hull or equipment or machinery have not been complied with and the ship thereby is not entitled to retain her class, the class will be withdrawn and the notation "Class withdrawn" (with date) will be made in the Supplement and the notation "LR class withdrawn" (with date) will be made in the next reprint of the Register Book. After one year the notation will be altered to "Classed LR until" (with date).

Reported Defects

1403 When it is found from reported defects in the hull or equipment or machinery that a ship is not entitled to retain her class in the Register Book, and the Owners fail to repair such defects in accordance with the Society's requirements, the class will be withdrawn and the notation "Class withdrawn—Reported defects" (with date) will be made in the Supplement and the notation "LR class withdrawn—Reported defects" (with date) will be made in the next reprint of the Register Book. After one year the notation will be altered to "Classed LR until" (with date).

Infringement of Freeboard Conditions

1404 Where any ship proceeds to sea with a less freeboard than that approved by the Committee or where the freeboard marks are placed higher on the ship's sides than the position assigned or approved by the Committee, the ship's class will be liable to be withdrawn.

Section 15

RECLASSIFICATION OF SHIPS

1501 When reclassification is desired for a ship for which the class previously assigned has been withdrawn, the Committee will direct a Special Survey for Reclassification, appropriate to the age of the ship and the circumstances of the case, to be carried out by the Society's Surveyors.

If at such survey the ship be found or placed in a good and efficient condition in accordance with the requirements of the Rules and Regulations the Committee will be prepared to reinstate her original class or assign such other class as may be deemed necessary.

The date of reclassification will be recorded in the Supplement to the Register Book.

15th July, 1971

Chapter C

PERIODICAL SURVEY REGULATIONS

Note. See C 3, C 4 or C 5 for additional requirements for Tankers, Liquefied Gas Carriers, or Dredgers, Hopper Dredgers, Sand Carriers, Hopper Barges and Reclamation Craft.

Section 1

ANNUAL AND DOCKING SURVEYS

Annual Surveys

- 101 Annual Surveys as required by B 801 should, whenever practicable, be held concurrently with statutory annual or other load line surveys.
 - 102 The Surveyor is to satisfy himself as to the efficient condition of the following:-

Hatchways on freeboard and superstructure decks, ventilator and air pipe coamings, exposed casings, fiddley openings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, side scuttles and deadlights, ash shoots and other openings, together with all closing appliances.

Means of ensuring watertightness of steel hatch covers.

Scuppers and sanitary discharges (so far as practicable) with valves; guard rails and bulwarks; freeing ports, gangways and lifelines; fittings and appliances for timber deck cargoes.

The Surveyor should satisfy himself regarding the freeboard marks on the ship's side,

103 Attention is to be paid to all parts of rod and chain gears. All pins are to be examined and the chain in the vicinity of the blocks is to be cleaned and examined for wear and tear. Any length of chain so worn that its mean diameter at its most worn part is reduced to the size given in Table D 34.2, is to be renewed.

All replacements of chains are to be subjected, under the Society's supervision, to the proof tests as set forth for short-link cables in P 8 and the certificates are to be produced. It is recommended that, in addition, the breaking test as required in P 8 should be applied to these chains, and that the tests be made at a proving establishment recognized by the Committee.

It is recommended that repaired chains be tested by the repairers and a certificate to that effect produced.

It is recommended that a set of spares be provided.

The various parts of the auxiliary steering gear are to be assembled and examined in order to ascertain that the gear is in good and workable condition.

104 The Surveyor is to examine internally a forward and an after hold or tank at the second Annual Survey after the fourth and subsequent Special Surveys on a dry cargo ship and the third and subsequent Special Surveys on a tanker.

DOCKING SURVEYS

(See B 802)

105 When a ship is in drydock or on a slipway she is to be placed on blocks of sufficient height, and proper staging is to be erected as may be necessary for the examination of the shell plating, sternframe and rudder.

Attention is to be given to parts of the structure particularly liable to excessive corrosion or to deterioration from causes such as chafing and lying on the ground and to any undue unfairness of the plating of the bottom.

GENERAL

- 106 At Annual and Docking Surveys the Surveyor should examine the ship so far as is practicable in order to satisfy himself as to her general condition.
 - 107 When chain cables are ranged the anchors and cables should be examined by the Surveyor.
- 108 The requirements for the survey of main and auxiliary engines, boilers and electrical equipment are set forth in C 6 to C 12.

Annual and Biennial Surveys of Fire Equipment

109 The arrangements for fire protection, detection and extinction in passenger ships are to be examined annually; in cargo ships the arrangements for fire detection and extinction are to be examined biennially.

Surveys carried out by the National Authorities of the countries in which ships are registered may be accepted as meeting these requirements.

SURVEYS FOR DAMAGE OR ALTERATIONS

110 At any time when a ship is undergoing damage repairs or alterations, any exposed parts of the structure normally difficult of access should be specially examined, e.g., if any part of the main or auxiliary machinery, including boilers, or insulation or fittings is removed for any reason the steel structure in way should be carefully examined by the Surveyor, or when cement in the bottom or covering on decks is removed the plating in way should be examined before the cement or covering is relaid.

Section 2

SPECIAL SURVEYS—HULL REQUIREMENTS

(For Tankers, see also C 3.)

- (A) At the Special Survey of ships under 5 years old.—The Requirements of an Annual Survey (see 102 and 103) are to be complied with, in addition to the following:—
- 201 The ship is to be placed on blocks of sufficient height in a drydock, or on a slipway; proper staging is to be erected as necessary and the shell plating, sternframe and rudder are to be examined.

The rudder is to be lifted for examination of pintles if considered necessary by the Surveyor.

202 The holds, 'tween decks, peaks, deep tanks, engine and boiler spaces, coal bunkers and other spaces are to be cleared and cleaned as necessary and examined. The bilges and limbers all fore and aft are to be cleaned and the structure examined. Platform plates in engine and boiler spaces are to be lifted as may be necessary for the examination of the structure below.

Where necessary close and spar ceiling, lining and pipe casings are to be removed for examination of the structure.

- 203 In ships having a single bottom, a sufficient amount of close ceiling is to be lifted all fore and aft on each side from the bottom and bilges to permit the structure below to be examined.
- 204 In ships having a double bottom, a sufficient amount of ceiling is to be removed from the bilges and inner bottom to enable the condition of the plating to be ascertained. If it is found that the plating is clean and in good condition, and free from rust, the removal of the remainder of ceiling may be dispensed with. The Surveyor may waive the removal of heavy reinforced compositions if there is no evidence of leakages, cracking or other faults in the composition.
- 205 The steelwork is to be exposed and cleaned as may be required for its proper examination by the Surveyor. Careful examination is to be made of parts of the structure particularly liable to excessive corrosion or to deterioration from causes such as chafing, lying on the ground, or handling of cargo.

Attention is to be given to the shell plating in way of side, bow and stern doors, ash shoots and other openings,

The Surveyor may require to ascertain by drilling or other approved means, the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or materially reduced in scantlings are to be made good by materials of the approved scantlings and quality. Attention is to be given to the structure in way of discontinuities. Surfaces are to be recoated as necessary.

- 206 In cases where the inner surface of the bottom plating is covered with cement, asphalt, or other composition, the removal of this covering may be dispensed with, provided it be inspected, tested by beating or chipping, and found sound and adhering satisfactorily to the steel.
- 207 Double bottom compartments, peak tanks and all other tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service.

Tanks may be tested affoat provided their internal examination is also carried out affoat.

Tanks forming part of the main structure, except as stated below, are to be cleaned and examined internally, special attention being given to tanks under boiler spaces. Tanks (excluding peak tanks) used exclusively for oil fuel or for oil fuel and fresh water ballast need not be examined internally provided, after external examination and testing in accordance with the requirements set out above, the Surveyor finds the condition of these compartments satisfactory.

Double bottom tanks used for oil fuel which require to be filled with sea water ballast after the fuel has been consumed need not all be examined internally provided that, after both the above external examination and testing and an internal examination of the after end of one forward tank, the Surveyor is satisfied with the condition.

- 208 All decks, casings and superstructures are to be examined. Attention is to be given to the corners of openings and other discontinuities in way of strength decks and top sides.
- 209 Wood decks or sheathing are to be examined; if decay or rot is found or the wood is excessively worn, the wood should be renewed. When a wood deck, laid on stringers and ties, originally required to be 75 mm (3 in) is worn to 65 mm (2.5 in), or 65 mm (2.5 in) to 50 mm (2 in), it is to be renewed.

Attention is to be given to the condition of the plating under wood decks, sheathing or other deck covering. If it is found that such coverings are broken or are not adhering closely to the plating, sections should be removed as necessary to ascertain the condition of the plating. (See also C 110).

210 The masts, standing rigging and anchors are to be examined. If the chain cables are ranged they should be examined. (See Table D 34.2 for renewals.)

The Surveyor should satisfy himself that there are sufficient mooring ropes on board and also that a towline is provided when this is a Rule requirement.

- 211 The steering gear, and its connections and control systems (main and alternative) are to be examined. The various parts of the auxiliary steering gear are to be assembled and examined.
- 212 The windlass (see C 602), hand pumps, suctions, watertight doors, air and sounding pipes are to be examined. When examining tanks internally the Surveyor should see that striking plates are fitted under sounding pipes.
- 213 Where holds are insulated for the purpose of carrying refrigerated cargoes, and the hull in way of the insulation was examined by the Society's Surveyors at the time such insulation was fitted, it will be sufficient to remove the limbers and hatches to enable the framing and plating in way to be examined; in other cases additional insulation is to be removed as necessary to satisfy the Surveyor as to the condition of the structure. (See also N 8.)

214 The Surveyor is to satisfy himself as to the efficient condition of the following:—

Means of escape from (a) machinery spaces, (b) crew and passenger spaces, (c) spaces in which crew are normally employed.

Means of communication between (a) bridge and engine room, (b) bridge and alternative steering position.

Helm indicator, protection of aft steering wheel and gear.

- 215 For surveys of machinery, electrical equipment, boilers, steam pipes and screw shafts, see C 6 to C 12.
- (B) At each Special Survey of ships between 5 and 10 years old.—The full requirements of 201 to 215 are to be complied with, together with the following:—
- 216 A sufficient amount of ceiling in the holds and in coal bunkers is to be removed from the bilges and inner bottom to enable the condition of structure in the bilges, the inner bottom plating, pillar feet, and the bottom plating of bulkheads and tunnel sides to be examined. If the Surveyor deems it necessary, the whole of the ceiling is to be removed.
- 217 In ships having a single bottom the limber boards and ceiling equal to not less than three strakes all fore and aft on each side are to be removed, one such strake being taken from the bilges. Where the ceiling is fitted in hatches, the whole of the hatches and at least one strake of ceiling in the bilges are to be removed. If the Surveyor deems it necessary the whole of the ceiling and limber boards are to be removed.
- 218 Tanks (excluding peak tanks) used exclusively for oil fuel or for oil fuel and fresh water ballast need not all be examined internally provided, from an external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank, the Surveyor is satisfied with the condition.

Lubricating oil tanks need not be examined internally.

- 219 The chain cables are to be ranged for inspection, and the anchors and chains examined. If any length of chain cable is found to be reduced in mean diameter at its most worn part to the extent indicated in Table D 34.2, it is to be renewed.
 - 220 The chain locker is to be cleaned and examined internally.
- (C) At each Special Survey of ships over 10 years old.—The full requirements of 201 to 220 are to be complied with, together with the following:—
 - 221 The steel work is to be cleaned and the rust removed.
- 222 Casings of air, sounding, steam and other pipes, spar ceiling and lining in way of the sidescuttles are to be removed as required by the Surveyor.
- 223 If the Surveyor is satisfied after removal of portions of the ceiling in the holds, that the steel work is in good condition, free from rust, and coated, the removal of the whole may be dispensed with. In coal bunkers, however, the whole of the ceiling is to be removed.
 - 224 Attention is to be given by the Surveyor to the inside of coal bunkers and the parts in way of the boilers.
- 225 Attention is also to be paid to the possibility of local wastage and grooving, e.g., at the shell plating along the heel of framing members.

226 All double bottom and other tanks are to be cleaned as necessary to permit their being examined internally, where this is required.

For ships of 10 and not more than 15 years old, tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil need not all be examined internally provided, from an external examination and testing and from internal examination of one double bottom tank forward and one aft and one deep tank, the Surveyor is satisfied with the condition.

For ships of 15 and not more than 20 years old, tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast or lubricating oil need not all be examined internally provided, from an external examination and testing and from an internal examination of at least one double bottom tank amidships, one forward and one aft and one deep tank, the Surveyor is satisfied with the condition. These tanks should be selected so that as many different tanks as possible are examined internally before the ship is 20 years old. For ships 20 years old or over, all tanks should be examined internally, but in those ships operating on a Continuous Survey basis and fitted with nested deep tanks comprising six or more adjoining tanks, such tanks need not all be examined internally provided that at each year of the survey cycle one selected tank from each nest is found from internal examination to be in good condition.

- 227 The cement chocks on the ship's sides at bilges and decks are to be examined, and portions removed, so that the condition of the shell plating and adjacent steel work can be ascertained. Portions of wood sheathing, or other covering, on steel decks are to be removed as considered necessary by the Surveyor in order to ascertain the condition of the plating.
- 228 Where the holds are insulated for the purpose of carrying refrigerated cargoes, the limbers and hatches are to be lifted, and sufficient insulation is to be removed in each of the chambers to enable the Surveyor to satisfy himself of the condition of the framing and plating. (See also N 8.)
 - 229 All mast wedging is to be removed and renewed as necessary.
- 230 For ships of 15 and not more than 20 years old, in addition to the drilling required by 205 to ascertain local wastage, the shell plating between the light and load waterlines and the strength deck plating outside the line of openings are to be gauged by drilling or other approved means to determine the amount of any general diminution in thickness. The gauging is to be done in at least two places in each strake of plating on each side within the midship half-length.
- (D) At the first Special Survey held after the ship is 20* years old and at every Special Survey thereafter—The full requirements of 201 to 229 are to be complied with, together with the following:—
- 231 In addition to the drilling required by 205 to ascertain local wastage, the shell plating and plating of strength decks are to be gauged by drilling or other approved means to determine the amount of any general diminution in thickness. The gauging is to be done in at least two places in each strake of plating on each side within the midship half-length. The remainder of the shell plating between the light and load waterlines and the strength deck plating outside the line of openings, all within the midship half-length, are also to be gauged.

All paint and rust is to be entirely removed before the plates are gauged by the Surveyor and the actual thicknesses are to be reported in detail to the Committee. Where drilled plates are renewed the thickness of adjacent plates in the same strake should be reported.

The thickness of bottom plating in way of cement is to be ascertained unless the Surveyor, after an internal and external examination, is entirely satisfied that this is unnecessary. Selected portions of the cement are to be removed from the bottom and bilge if required by the Surveyor.

Chapter C

232 Where the holds are insulated for the purpose of carrying refrigerated cargoes, the limbers and hatches are to be lifted, and sufficient additional insulation is to be removed in each of the chambers to enable the Surveyor to satisfy himself of the condition of the steel structure, and to enable the thickness of the shell plating to be ascertained as required by 231.

Section 3

SPECIAL SURVEYS-TANKERS

HULL REQUIREMENTS ADDITIONAL TO THOSE STATED IN C 2

Preparation and Inspection of Tanks

301 At all Special Surveys all cargo tanks and cofferdams are to be cleaned out, thoroughly cleared of gas, and examined. Every precaution is to be taken to ensure safety during inspection.

Attention is to be given to the inside of the bottom plating in order to ensure that there is no excessive pitting of the plating. When extensive pitting is found care should be taken to preserve the longitudinal strength of the bottom by the requisite renewals or rapairs. In cases where cement has been laid in the bottom the Surveyor is to satisfy himself that there is no active corrosion under the cement.

- 302 The strums of the cargo suction pipes are to be removed to facilitate examination of the shell plating and bulkheads in that vicinity, unless other means for visual inspection of these parts are provided.
 - 303 The attachment to the structure and condition of anodes in tanks is to be examined.

Testing

- 304 Each cargo tank bulkhead is to be tested at Special Surveys A and B by filling alternate tanks with water to the top of the hatchway. But at subsequent Special Surveys, or earlier if considered necessary by the Surveyor, all tanks are to be tested.
- 305 Tanks may be tested when the ship is afloat, provided the internal examination of the bottom is also carried out afloat.
- 306 Where extensive repairs have been effected to the shell plating, the tanks should be tested to the Surveyor's satisfaction.

Determination of Thickness

307 The requirements of 231 are to be complied with at every Special Survey after the ship is 10 years old except that, in respect of the deck plating, every deck plate within the midship half-length is to be gauged. All gaugings are to be taken in way of tanks.

Section 4

LIQUEFIED GAS CARRIERS

ANNUAL AND SPECIAL SURVEYS-REQUIREMENTS ADDITIONAL TO THOSE STATED IN C 1, C 2 AND C 3

Preparation before Survey

401 Prior to inspection of cargo tanks, cofferdams, associated piping, fittings or equipment, the respective items are to be cleaned and thoroughly cleared of gas. Every precaution is to be taken to ensure safety during inspection.

Annual Surveys

402 Where the maximum vapour pressure for which the cargo tanks have been approved as recorded in the Register Book is 0,7 kg/cm² (10 lb/in²), or less, the inner surfaces of the tanks are to be examined annually.

Where submerged electrically driven pumps are fitted in the cargo tanks, the pumps, motors, control devices and interlocks are to be examined annually as required by 404.

Liquid level indicating devices, high level alarms, monitoring systems for revealing possible gas leakage and arrangements for inerting the tanks and containment spaces are to be examined and tested to ascertain that they are in good working order.

Special Surveys

403 At each Special Survey of the ship the tanks are to be examined internally, also externally so far as practicable, particular attention being paid to the plating in way of supports and securing arrangements, mountings and pipe connections, also to sealing arrangements at the deck.

Where the tanks are insulated, portions of the insulation are to be removed if required by the Surveyor to enable him to ascertain the condition of the plating.

Internal fittings are to be examined, all valves and cocks in direct communication with the interiors of the tanks are to be opened out for inspection and any pipes connecting them to the tanks are to be examined internally so far as practicable.

Liquid level indicating devices, high level alarms, monitoring systems for revealing possible gas leakage and arrangements for inerting the tanks and containment spaces are to be examined and tested to ascertain that they are in good working order.

Where provision is made for recording the temperature of the ship's structure adjacent to the tanks, the correct functioning of the apparatus, including audible alarms, is to be verified.

Pressure relief valves are to be opened out for inspection and subsequently adjusted to lift at a pressure not more than three per cent above the maximum vapour pressure for which the tanks have been approved. The valves may be removed from the tanks for the purpose of making this adjustment which may be effected under pressure of air or other suitable medium.

Vacuum relief valves are to be opened out, examined and tested to establish that they are in good working order.

Where the approved maximum vapour pressure of the cargo tanks is 0,7 kg/cm² (10 lb/in²), or less, the tanks are to be tested by a head of water 2,45 m (8 ft) above the top of the tank or 610 mm (2 ft) above the top of the hatch, whichever is the greater. Where access to the outside of the cargo tanks is not possible other proposals for leak testing of the cargo tanks will be considered.

Where the approved maximum vapour pressure is above 0,7 kg/cm² (10 lb/in²), the tanks are to be tested by pressure of water equal to one and a quarter times the approved maximum vapour pressure. Where these tanks are insulated, at the second Special Survey and at each alternate Special Survey thereafter, the insulation is to be removed in way of all supports and connections to the tanks prior to the water pressure test.

Where non-corrosive cargoes only are carried in uninsulated cylindrical tanks fitted in the ship with their longitudinal axes approximately vertical and the cargoes are not discharged by the admission of water to the tanks, proposals will be considered, upon application by the Owners, to omit the hydraulic test provided the tanks have been constructed in accordance with the Rules for Welded Pressure Vessels, Class 1, including stress relieving heat treatment, and the Surveyor is satisfied with their internal and external condition. Proposals to limit the amount of opening out of valves, cocks and pressure relief valves at each Special Survey will be considered provided all valves, etc., are seen in rotation in the course of each two consecutive Special Surveys.

Where insulation is attached to the hull structure, special consideration will be given to the necessity of removing it at Special Surveys but, in general, provided the Surveyor is satisfied that it is adhering properly and there are no traces of cold spots, this will not be required until the ship is at least eight years old. An examination of the wing tanks, double bottom tanks and transverse cofferdams, when the cargo tanks are loaded with liquefied gas at the minimum approved temperature, will be required at the Special Survey or at a convenient date immediately prior thereto.

404 Where submerged electrically driven pumps are fitted in the cargo tanks, at each Annual and each Special Survey the pumps and motors are to be withdrawn from the tanks and opened out for examination of the condition of the stator winding insulation, evidence of any damage due to thermal expansion and contraction and bearing wear. Any sludge deposits in the motor windings or casings are to be removed and insulation resistances, including those of the motors and supply cables, are to be measured before opening out and after refitting. The portions of supply cables within the cargo tanks and the cable glands are to be examined for signs of deterioration and/or gas leakage.

Chapter C

The control devices and interlocks actuated by pressure or liquid level in the tanks and master key switches, which cut off the supply of current to the motors, are to be checked under simulated working conditions and if necessary re-calibrated.

Where deep well pumps are fitted in the cargo tanks, at each Special Survey the control devices which cut off the supply of current to the motors are to be checked under simulated working conditions and if necessary re-calibrated.

405 Where refrigeration equipment is installed, either for maintaining the liquid cargo at the carrying temperature or for re-liquefying the "boil-off" and returning it to the tanks, Running and Special Surveys of the equipment are to be carried out in accordance with the requirements of Chapter N, so far as applicable.

In addition, at each Survey the ventilating fans and motors for the refrigerating machinery rooms are to be examined under working conditions and the operation of the temperature indicating equipment and the refrigerating plant checked by examination of the log records.

Section 5

DREDGERS, HOPPER DREDGERS, SAND CARRIERS, HOPPER BARGES AND RECLAMATION CRAFT

501 The survey requirements of Chapter C are to be complied with, and in addition the requirements listed below are to be complied with as applicable. Where surveys are required to be made on dredging or hopper equipment such as gantries, bottom doors and their operating gear, positioning spuds and suction pipe attachments, these will be limited to the extent considered necessary by the Surveyor to satisfy himself that their condition or mal-function will not adversely affect the ship's structure.

Docking Surveys

502 Where applicable the docking survey is to include the examination of hopper doors and their fittings, and of hopper valves.

Special Surveys for ships under 5 years old

503 Hoppers are to be cleared and cleaned as necessary and examined.

Where applicable, hopper doors or valves are to be opened and closed as far as is practicable, but keel blocks need not normally be moved specially to permit this to be done.

The integrity of hopper overflows and diluting water inlet and distribution structures is to be confirmed. Weir valves and sluices are to be tested to ensure proper operation, particular attention being paid to the lower weir when weirs are fitted at more than one level.

Attention is to be given to shell plating in way of hopper overflows.

The attachment to the ship's structure of all main items of dredging equipment, including gantries, "A" frames and spud control gear supports, is to be carefully examined to ensure that no fracture is present.

Special Surveys-Ships between 5 and 10 years old

504 Additional requirements as for ships under 5 years old.

Special Surveys-Ships over 10 years old

505 Attention is to be given by the Surveyor to the structure in way of dredging pumps.

Hopper doors and valves are to be checked for proper operation and their hinges, control gear and other fittings examined for wear or distortion. All seals and wear-down strips are to be replaced if necessary, but a watertight seal is not normally required. Attention is to be paid to areas likely to be suffering from excessive erosion.

Those items of dredging gear and equipment whose efficiency is not part of classification but whose failure or malfunctioning is, nevertheless, likely adversely to affect the ship's structure, are to be examined to ensure that the structural integrity of the ship is maintained.

GENERAL REQUIREMENTS-MACHINERY

APPLICABLE TO ALL SHIPS

At each Survey held in dry dock

601 When the ship is in drydock the propeller, stern bush and sea connection fastenings and the gratings at the sea inlets are to be examined. The clearance in the stern bush or the efficiency of the oil gland should be ascertained.

Complete Surveys

602 At each Complete Survey required by B 807 the following parts are to be examined:-

SEA CONNECTIONS

While the ship is in drydock all openings to the sea in the machinery spaces and pump rooms with the valves, cocks and the fastenings with which these are connected to the hull.

SHAFTING

All shafts (except screw and tube shafts for which special arrangements are detailed in C 12), thrust block and all bearings. The lower halves of bearings need not be exposed if alignment and wear are found acceptable.

REDUCTION GEARS, complete with all wheels, pinions, shafts, bearings and gear teeth.

AUXILIARY Engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.

STEERING MACHINERY

WINDLASS

EVAPORATORS and their safety valves, which should be seen in operation under steam.

SECURING ARRANGEMENTS

The holding down bolts and chocks of main and auxiliary engines, gear cases, thrust blocks and tunnel bearings.

AIR RECEIVERS

All air receivers for essential services with their mountings, valves and safety devices are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

Pumping Arrangements

The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and, together with pipes, are to be examined and tested under working conditions. The oil fuel, feed and lubricating oil systems and the ballast connections and blanking arrangements to deep tanks which may carry liquid or dry cargoes, together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

FUEL TANKS AND FITTINGS

Fuel tanks which do not form part of the ship's structure are to be examined and if considered necessary by the Surveyor they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. All mountings, fittings and deck controls are to be examined so far as practicable.

Chapter C

SPARE GEAR

The spare gear is to be checked.

REMOTE AND/OR AUTOMATIC CONTROLS

Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

In addition to the above, detailed requirements for steam and oil engines, electrical installations and boilers are given in C 7, C 8, C 9 and C 10 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g., vibration indicators) and operational records.

Section 7

STEAM ENGINES—DETAILED REQUIREMENTS

Complete Surveys

701 In addition to the requirements of C 6 the working parts of the main engines and attached pumps and of auxiliary machinery used for essential services including bulkhead stop valves, manœuvring valves, cylinders, pistons, valves and valve gear, piston rods, connecting rods, crossheads and guides, the crank shafts of reciprocating engines and the blading, rotors and casings of turbine machinery are to be opened up and examined.

Condensers, steam reheaters, desuperheaters which are not incorporated in the boilers and any other appliances used for essential services are to be examined to the satisfaction of the Surveyor, and if considered necessary they are to be tested.

The manœuvring of the engines is to be tested under working conditions.

702 Exhaust steam turbines supplying power for main propulsion purposes in conjunction with reciprocating engines are, together with their gearing and appliances, steam compressors or electrical machinery, to be examined so far as practicable. Where cone connections to internal gear shafts are fitted, the coned ends are to be examined so far as practicable.

703 In steam ships having essential auxiliary machinery driven by oil engines, the prime movers of these auxiliaries are to be examined as detailed in C 801.

Section 8

OIL ENGINES-DETAILED REQUIREMENTS

Complete Surveys

801 In addition to the requirements of C 6 the Complete Survey is to consist of the opening out and examination of the following parts: cylinders, covers, valves and valve gear, fuel pumps and fittings, scavenge pumps, scavenge blowers and their prime movers, superchargers, compressors their intercoolers filters and/or oil separators and safety devices, pistons, piston rods, crossheads, guides, connecting rods, crank shafts and all bearings, clutches, reverse gears, attached pumps, cooling system, crankcase door fastenings and explosion relief devices. Selected pipes in the starting air system are to be removed for internal examination and hammer-tested. If an appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors. The electric ignition system, if fitted, is to be examined and tested. The manœuvring of engines is to be tested under working conditions.

Where steam is used for essential purposes, the condensing plant, feed pumps, and oil fuel burning plant, are to be examined and the steam pipes examined and tested as detailed in C 11.

802 Gas turbines and free piston gas generators: in addition to the requirements of C 6, the Complete Survey is to consist of the opening and examination of the following parts: the blading, rotors and casings of the turbines, the impellers or blading, rotors and casings of the air compressors, the combustion chambers, burners, intercoolers, heat exchangers, gas and air pressure piping and fittings, starting and reversing arrangements.

Where gas turbines operate in conjunction with free piston gas generators, the following parts of the latter are to be opened and examined: the gas and air compressor cylinders and pistons and the compressor end covers, the valves and valve gear, fuel pumps and fittings, synchronizing and control gear, cooling system, explosion relief devices, gas and air piping, receivers and valves including by-pass. The manœuvring of engines is to be tested under working conditions.

Section 9

ELECTRICAL EQUIPMENT

- 901 At each Complete Survey the electrical equipment is to be examined and tested in accordance with 902 to 911.

 Note.—In cases where the Committee have consented to Continuous Surveys, the electrical equipment may also be included in the survey cycle. (See B 808.)
- 902 A test for insulation resistance is to be made on the cables, switchgear, generators, motors, heaters, lighting fittings, etc., and the insulation resistance is to be not less than 100 000 ohms between all insulated circuits and earth. The installation may be sub-divided to any desired extent by opening switches, removing fuses or disconnecting appliances for the purpose of this test.
- 903 The fittings on main and emergency switchboards, section boards and sub-distribution fuse boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.
- 904 Generator circuit-breakers are to be tested, so far as practicable, to verify that the protective devices including preference tripping relays, if fitted, operate satisfactorily.
- 905 The electric cables are to be examined so far as practicable without undue disturbance of fixtures or casings unless opening up is considered necessary as a result either of observation or of the tests required by 902.
- 906 The generator prime movers are to be surveyed as required by C 7 and C 8 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and, if considered necessary, are to be operated so far as practicable under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.
- 907 Where transformers or electrical apparatus associated with supplies to essential services are oil-immersed, the Owners are to arrange for samples of oil to be taken and tested for breakdown voltage, acidity and moisture by a competent testing authority and a certificate giving the test results is to be furnished to the Surveyor.
- 908 Where electro-magnetic couplings are fitted, the air gaps to be measured and reported, and any excessive eccentricity corrected. The couplings and associated switchgear are to be examined and tested.
- 909 Navigation light indicators are to be tried under working conditions and correct operation on the failure of supply and failure of navigation lights verified.
- 910 In passenger ships the emergency source of power and its associated circuits and, where fitted, the temporary source of power and its automatic arrangements are to be tested. (See M 111.)

In cargo ships the emergency source of power and its associated circuits are to be tested. (See M 111.)

Electric Propelling Machinery

911 Where the ship is electrically propelled, the propulsion motors, generators, cables, and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined and the insulation

resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked so far as practicable. Insulating oil, if used, is to be tested in accordance with 907. Interlocks intended to prevent unsafe operations or unauthorized access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

Section 10

BOILER SURVEYS

1001 Water tube boilers supplying steam to the main propelling machinery (other than cylindrical boilers having corrugated or plain furnaces in conjunction with water tubes) and steam heated steam generators are to be surveyed at two-yearly intervals. All other boilers (including domestic boilers having a working pressure exceeding 3,5 kg/cm² (50 lb/in²) and a heating surface exceeding 4,65 m² (50 ft²)), also press boilers and similar apparatus in floating whale oil factories, and exhaust gas steam generators and economizers, are to be surveyed at two-yearly intervals until they are 8 years old and subsequently annually. In fired boilers employing forced circulation the pumps used for this service are to be opened and examined at each boiler survey.

1002 At the surveys described in 1001 the boilers, superheaters, economizers and air heaters are to be examined internally and externally, and where considered necessary the pressure parts are to be tested by hydraulic pressure and thickness of plates and tubes and size of stays are to be ascertained to determine a safe working pressure. The principal mountings on boilers, superheaters and economizers are to be opened up and examined and the safety valves adjusted under steam to a pressure not greater than 3 per cent above the approved working pressures of the respective parts. The remaining mountings are to be examined externally and are to be opened up for internal examination if considered necessary by the Surveyor. Collision chocks, rolling stays and boiler stools are to be examined and maintained in efficient condition.

1003 The oil fuel burning system is to be examined under working conditions and a general examination made of fuel tank valves, pipes, deck control gear and oil discharge pipes between pumps and burners.

1004 At each survey of a cylindrical boiler which is fitted with smoke tube superheaters, the saturated steam pipes are to be examined as detailed in C 1104.

Section 11

STEAM PIPES

Steel Pipes

1101 INCIDENCE OF SURVEYS.—Saturated steam pipes, also superheated steam pipes where the temperature of the steam at the superheater outlet is not over 454°C (850°F), are to be surveyed at the second and each subsequent Special Survey. Superheated steam pipes where the temperature of the steam at the superheater outlet is over 454°C (850°F) are to be surveyed at each Special Survey, including the first.

SCOPE OF SURVEYS

1102 PIPES HAVING BOLTED JOINTS.—At each survey a selected number of main steam pipes, also of auxiliary steam pipes over 75 mm (3 in) internal diameter supplying steam for essential services at sea, are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. The pipes are, so far as practicable, to be selected for examination and hydraulic test in rotation so that in the course of surveys all sections of the pipe line will be tested.

1103 PIPES HAVING WELDED JOINTS.—Where main and/or auxiliary steam pipes of the category described in 1102 have welded joints between lengths of pipe and/or between pipes and valves, the lagging in way of the welds is to be removed, the welds examined and, if considered necessary by the Surveyor, crack detected. Pipe ranges having welded joints are to be hydraulically tested to 1,5 times the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure.

1104 CYLINDRICAL BOILERS HAVING SMOKE TUBE SUPERHEATERS.—Where the saturated steam pipes adjoining the saturated steam headers are situated partly in the boiler smoke boxes, all such pipes adjoining and cross-connecting these headers in the smoke boxes are, at the surveys required by 1101, to be included in the pipes selected for examination and testing as defined in 1102. Where the saturated steam pipes inside the smoke boxes consist of steel castings of substantial construction, these requirements need only be applied to a sample casting. Where steel castings are not fitted, the Surveyor is to satisfy himself of the condition of the ends of the saturated steam pipes in the smoke boxes at each boiler survey and, if he considers it necessary, a sample pipe is to be removed for examination.

1105 As an alternative to the requirements of 1102, and provided the saturated steam pipes in smoke boxes are dealt with as detailed in the first paragraph of 1104, the remainder of the pipes may, if the Owner wishes, be hydraulically tested in place to 1,5 times the working pressure. Lagging is to be removed as required by the Surveyor to permit effective examination.

Copper Pipes

1106 At the second and at each subsequent Special Survey all copper steam pipes over 75 mm (3 in) internal diameter supplying steam for essential services at sea are to be hydraulically tested to twice the working pressure. At these surveys any of the pipes which may be subject to bending and/or vibration, such as those having expansion or other bends, and closing lengths adjacent to steam driven machinery, are to be annealed before being tested.

Section 12

SCREW SHAFTS AND TUBE SHAFTS

1201 Screw shafts and tube shafts are to be drawn periodically for examination by the Society's Surveyors.

Where shafts are fitted with continuous liners or approved oil glands, or are made of approved corrosion resisting material, they normally become due for survey at intervals of 3 years for single screw ships and 4 years for ships having two or more screws. All other shafts should be drawn at intervals of 2 years.

1202 On the application of Owners, surveys of shafts of single screw ships having continuous liners or approved oil glands, or made of approved corrosion-resisting material may be held at intervals of 4 years, provided the keyway is of the sled-runner or round-ended type having adequate root radius, any sharp edge around the keyway at the surface of the shaft is removed by filing or other suitable means and, at each survey, the shaft is examined by an efficient crack detection method over a length from the after end of the liner (or after end of the stern tube for shafts not fitted with continuous liners) to a position at about one-third of the length of the cone from the large end. Upon application by the Owners and provided the keyway is as described above, a four-year period will also be allowed before the first survey of the shaft of a new single screw ship and may be allowed for a new or previously unused spare shaft fitted to an existing ship. At the first and subsequent periodical surveys the forward portion of the shaft cone is to be examined by an efficient crack detection method.

1203 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owners.

Section 13

CLASSIFICATION OF SHIPS NOT BUILT UNDER SURVEY

1301 When classification is desired for a ship not built under the supervision of the Society's Surveyors, application should be made to the Committee in writing.

Hull and Equipment

1302 Plans showing the main scantlings and arrangements of the actual ship and any proposed alterations are to be submitted for approval. These should comprise midship section, longitudinal section and decks, and such other plans

as may be requested. If plans cannot be obtained or prepared by Owners, facilities are to be given for the Society's Surveyor to take the necessary information from the ship.

Particulars of the process of manufacture and testing of the material of construction should be furnished.

1303 In all cases the full requirements of C 201 to C 230 are to be carried out. In the case of tankers the requirements of C 301 to C 306 are also to be carried out. Tankers over 10 years old are in addition to comply with C 307, and other ships over 20 years old with C 231 and C 232. During the survey the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and in order to ascertain the amount of any deterioration, parts of the structure will require to be drilled as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. Fire protection, detection and extinction are to be in accordance with the Rules (see Chapter F). Ships of recent construction will receive special consideration.

1304 When the full survey requirements indicated above cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

Machinery

1305 To facilitate the survey, plans of the following items, together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings should be furnished:—

General pumping arrangements, including air and sounding pipes. (Shipbuilder's plan.)

Pumping arrangements at the forward and after ends of oil tankers and drainage of cofferdams and pump rooms.

General arrangement of cargo piping in tanks and on deck of oil tankers.

Piping arrangements for cargo oil (F.P. 60°C (140°F) or above, closed cup test).

Bilge, ballast and oil fuel pumping arrangements in the machinery space, including the capacities of the pumps on bilge service.

Arrangement and dimensions of main steam pipes.

Arrangement of oil fuel pipes and fittings at settling and service tanks.

Arrangement of oil fuel piping in connection with oil burning installations.

Oil fuel and cargo oil overflow systems, where these are fitted.

Arrangement of boiler feed systems.

Oil fuel settling, service and other oil fuel tanks not forming part of the ship's structure.

Plans of piping are to be diagrammatic.

Boilers, superheaters and economizers.

Air receivers.

Crank, thrust, intermediate and screw shafting.

Clutch and reversing gear with methods of control.

Reduction gearing.

Propeller (including spare propeller if supplied).

Electrical circuits.

Note. Plans additional to the above should not be submitted unless the machinery is of a novel or special character affecting classification.

Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted. Particulars are to be given of the spare gear carried for machinery and control gear and whether maintenance is by repair or replacement.

TORSIONAL VIBRATION CHARACTERISTICS

For new ships and ships which have been in service less than 8 years calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration as required for ships constructed under Special Survey. For older ships the circumstances will be specially considered in relation to their service record and type of machinery installed.

Where calculations are not submitted the Committee may require that the machinery certificate be endorsed to this effect.

When desired by the Owners the calculations and investigation of torsional vibration characteristics of machinery may be carried out by the Society upon special request.

1306 The main and auxiliary machinery, also feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys, and their working pressures are to be determined from their actual scantlings in accordance with the Rules.

The screw shaft is to be drawn and examined.

The steam pipes are to be examined and tested as required by C 11.

The bilge, ballast and oil fuel pumping arrangements are to be examined and amended as necessary to comply with the Rules.

Oil burning installations are to be examined as required at Complete Surveys and found, or amended, to comply with the requirements of the Rules; they are also to be tested under working conditions.

The electrical equipment is to be examined as required at Complete Surveys.

The spare gear is to be in accordance with the Rules.

The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

First entry reports are to be prepared by the Surveyors.

1307 Where classification with the Society is desired for a ship which is classed by another recognized Society, special consideration will be given to the scope of the machinery survey.

Periodical Surveys

1308 Periodical surveys are subsequently to be held as in the case of ships built under survey.

15th July, 1971

NOTE

Chapter D of these Rules is applicable only to ships of 90 m (295 ft) and over in length.

For ships under 90 m (295 ft) in length, see Chapter SD in the latest cumulative Notice to these Rules in association with the 1967 Rules.

Chapter D

STEEL SHIPS

(See Note on page 32)

Section 1

GENERAL

Application

101 This Chapter applies to sea-going dry cargo ships of normal form and proportions of 90 m (295 ft) and over in length.

Ships of unusual form or proportions, or intended for the carriage of special cargoes, will receive individual consideration on the basis of the general standards of these Rules. (For the carriage of liquefied gases, see D 70, D 71 and D 72.)

The scantlings and arrangements in passenger ships will be specially considered in relation to the general design features.

For ships under 90 m (295 ft) in length and for tugs, dredgers and hopper barges, see page 32.

102 Where the ratio of length to depth exceeds 16, increased longitudinal scantlings may be required (length and depth as defined in D 2).

Ballasting

103 Attention should be given to the amount and distribution of water ballast. It has been found that satisfactory service has been obtained when the draught forward is not less than 0,027L and the longitudinal radius of gyration of the ballasted ship is less than 0,25L.

Material

104 Mild steel is to comply with P 2. A grade higher than A is only required when specifically mentioned in this Chapter.

Where higher tensile steel complying with P 3 is used the scantlings may be reduced in accordance with D 65.

105 Aluminium alloy used for superstructures, deckhouses, hatch covers or other structural members is to comply with P 12.

Method of Construction

106 The Rules apply to all welded construction.

Distribution of Continuous Longitudinal Material

107 The midship scantlings are to extend over 0,4L amidships and are to be reduced gradually to those permitted at the ends except as otherwise required by these Rules.

Equivalents

108 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted.

Plans

109 Plans covering the following items are to be submitted:—

Midship section.

Longitudinal strength calculations.

Longitudinal section.

Shell plating (indicating extent of flat of bottom forward).

Decks.

Watertight bulkheads.

Pillars and girders.

Deep tanks.

Oil fuel bunkers.

Arrangement of fore body.

Rudder.

Sternframe.

Propeller brackets.

Main engine and thrust seating.

Arrangement of after end.

Superstructure and deckhouse.

Hatchways.

Strengthening for navigation in ice.

Masts and derrick posts.

Scheme of welding.

Particulars for calculation of freeboard.

Loading manual.

Fire protection, detection and extinction arrangements. The information required by D 302, D 303, D 304 and D 305 is to be submitted as may be necessary.

Note. It is recommended that a plan be carried in the ship indicating the position and grades (other than Grade A) of hull structural steel and any recommendations for welding, working and treatment of such steels.

Corrosion Control

110 Where an approved system of corrosion control is provided in deep tanks, double bottom tanks, topside tanks, hopper side tanks, side ballast tanks, peak tanks or oil fuel bunkers, the reductions in thickness given in Table D 1.1 will be allowed.

If cathodic protection is adopted for water ballast tanks and reductions are desired at the top of a deep tank within 1,5 m (5.0 ft) of the deckhead, then this part of the tank is to be coated.

Where reductions are desired, full particulars of the protection proposed are to be submitted and the plans are to show both the Rule and reduced scantlings. An appropriate notation may be made in the Register Book.

TABLE D 1.1

Item	Permissible reduction in thickness
All structural items wholly within the protected tank with the exception of longitudinals on the bottom, side, strength deck, and on other longitudinal strength members.	10%
Items of which one side only is within the protected tank, e.g., transverse bulkhead at end of deep tank, tank top plating, etc. (see Note 1). Longitudinals on the bottom, side, deck and on other longitudinal strength members. Keel (see Note 2). Bottom shell (see Note 2). Side shell (see Note 2). Deck plating (see Note 2).	5%

Notes. 1. The tank top, and lower strakes of longitudinal and transverse bulkheads where liable to suffer grab or bull-dozer damage only to be reduced by 5 per cent even if protected on both sides.

2. Reduction not affected by means of external protection.

Modulus of Stiffeners, Girders, etc.

111 For longitudinals, side frames and bulkhead stiffeners the Rule section modulus required by the appropriate formula is that of the section in association with 610 mm (24 in) of plating having the same thickness as the shell, deck or bulkhead plating as appropriate. Where the attached plating is of varying thickness, the mean thickness over the span is to be used.

The effective section moduli of rolled sections and the area of the section without plating are given in the publication "Geometric Properties of Rolled Sections and Built Girders".

The effective section moduli of flat bars or built sections may be obtained from curves in the above publication.

112 For girders (including weather deck hatch side coamings), transverses, webs, etc., the Rule section modulus required by the appropriate formula is that of the member in association with an effective area of attached plating as given in D 5304, unless otherwise specified.

Section 2

DEFINITIONS

201 Length ∟ is the distance, in metres (feet), on the summer load waterline from the fore side of the stem to the after side of rudder post, or to the centre of the rudder stock if there is no rudder post. ∟ is not to be less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline.

Amidships is to be taken as the middle of the length L measuring from the fore side of the stem.

In ships with unusual stern arrangement the length L will be specially considered.

202 Breadth B is the greatest moulded breadth, in metres (feet).

203 Depth D is measured, in metres (feet), at the middle of the length L from top of keel to top of the deck beam at side on the uppermost continuous deck or as defined in appropriate Sections.

When a rounded gunwale is arranged the depth D is to be measured to the continuation of the moulded deck line.

204 Draught d is the summer draught, in metres (feet), measured from top of keel.

205 Passenger ship is a ship, engaged on international voyages, which carries more than twelve passengers.

206 Other parameters are defined in the appropriate Sections.

Section 3

LONGITUDINAL STRENGTH

301 The section modulus at deck and keel is not to be less than the greatest of the following values:—

- (a) M cm³
- (b) $\frac{M}{3} + 92 \text{ SWBM}_{L} (C_b + 0,20) \text{ cm}^3$
- (c) $\frac{0.85M_1}{3f} + 92 \text{ SWBM}_B (C_{b1} + 0.20) \text{ cm}^3$

where M = f K B ($C_b + 0.70$) $\times 10^5$,

$$M_i = f K B (C_{bi} + 0.70) \times 10^5,$$

f = 0,85 for the class 100A1 or 100A1 "Strengthened for Heavy Cargoes", 0,90 for the class 100A1 "Strengthened for Heavy Cargoes—Specified holds may be empty".

or in British units:-

- (a) M in2ft
- (b) $\frac{M}{3} + \frac{SWBM_{L}(C_{b} + 0.20)}{6.9}$ in 2ft
- (c) $\frac{0.85 \text{ M}_1}{3t} + \frac{\text{SWBM}_B (C_{bi} + 0.20)}{6.9} \text{ in}^2 \text{ft}$

where M = f K B ($C_b + 0.70$) $\times 10^3$,

$$M_1 = f K B (C_{b1} + 0.70) \times 10^3,$$

f = 0.85 for the class 100A1 or 100A1 "Strengthened for Heavy Cargoes", 0.90 for the class 100A1 "Strengthened for Heavy Cargoes—Specified holds may be empty",

(See D 3A for Carriage of Ore Cargoes—For these Rules, a stowage rate of 0,70 m³/tonne (25 ft³/ton), based on the cubic capacity, excluding hatchways, of the holds concerned is taken as the demarcation between "Ore Cargoes" and "Heavy Cargoes".)

K is to be determined from Table D 3.1,

C_b = the moulded block coefficient at load draught or 0,045 L, whichever is the greater, but is not to be taken as less than 0,60. The block coefficient is to be determined using the length L as defined in D 201, C_{b1} = the moulded block coefficient at the ballast or part loaded draught but is not to be taken as less than 0,60. The block coefficient is to be determined using the length L as defined in D 201. (See also D 103),

B = the moulded breadth, in metres (feet),

SWBM_L = the maximum still water bending moment, in tonnes metres (tons feet), hogging or sagging in loaded conditions (see 302 to 305),

SWBM_B = the maximum still water bending moment, in tonnes metres (tons feet), hogging or sagging in ballast or part loaded conditions (see 302 to 305).

Note. When the required modulus is M, the maximum associated still water bending moment in loaded conditions will be

$$\frac{7,25~\text{M}}{C_{\text{b}}+0,20}\times10^{-3}~\text{tonne m}~\left(\frac{4\cdot6~\text{M}}{C_{\text{b}}+0\cdot20}~\text{ton ft}\right)$$

which corresponds to a stress of

$$\frac{7,25}{C_{\rm b} + 0,20} \text{ kg/mm}^2 \left(\frac{4 \cdot 6}{C_{\rm b} + 0 \cdot 20} \text{ ton/in}^2 \right)$$

302 The still water bending moment calculation for homogeneous and, if applicable, non-homogeneous load conditions and for the ballast or part loaded conditions (departure and arrival) is to be submitted.

303 When a class notation is desired permitting certain holds to be empty, curves of still water bending moment and shear force are to be submitted. These may also be required when unusual loading conditions are proposed.

304 The method of calculating the still water bending moment and shear force curves (where applicable) is to be submitted for approval. The assumed longitudinal distribution of lightship weight is also to be submitted.

305 When the still water bending moment is required to be calculated for conditions other than homogeneous load conditions, the approved loading is to be incorporated in the Loading Manual.

The Loading Manual is to be submitted for approval of the longitudinal distribution of cargo and ballast as shown therein.

306 In order to guard against high stresses being imposed through an unsatisfactory cargo or ballast loading, it is recommended that an approved means of determining the suitability of loading be placed on board.

TABLE D 3.1—VALUES OF K

LENGTH	K	Difference in K per 1 m difference in L	LENGTH	K	Difference in K per 1 m difference in L	LENGTH	К	Difference in K per 1 m difference in L
Metres			Metres		0,0396	Metres		0,0670
90	0,747	0.0000	165	2,950	0.0414	240	7,025	0.0000
95	0,865	0,0236	170	3,157	0,0414	245	7,369	0,0688
		0,0240			0,0430		100000000000000000000000000000000000000	0,0706
100	0,985	0.0949	175	3,372	0.0449	250	7,722	0.0700
105	1,106	0,0242	180	3,596	0,0448	255	8,083	0,0722
1000		0,0244			0,0468		10.4.00,10	0,0730
110	1,228	0,0246	185	3,830	0,0488	260	8,448	0,0736
115	1,351	0,0240	190	4,074	0,0400	265	8,816	0,0150
400	1 470	0,0250	405	4.000	0,0510	070	0.100	0,0740
120	1,476	0,0260	195	4,329	0,0530	270	9,186	0,0744
125	1,606		200	4,594		275	9,558	11 11 12 12 12 12 12 12 12 12 12 12 12 1
130	1,744	0,0276	205	4,868	0,0548	280	0.091	0,0746
130	1,144	0,0294	200	4,000	0,0564	200	9,931	0,0748
135	1,891		210	5,150		285	10,305	
140	2,046	0,0310	215	5,440	0,0580	290	10,680	0,0750
110	2,010	0,0328		0,110	0,0598	200	10,000	0,0754
145	2,210	0.0944	220	5,739	0.0010	295	11,057	0.0760
150	2,382	0,0344	225	6,047	0,0616	300	11,437	0,0760
		0,0362			0,0634			0,0770
155	2,563	0,0378	230	6,364	0,0652	305	11,822	
160	2,752	0,0310	235	6,690	0,0002			
17000		0,0396			0,0670			

307 All continuous longitudinal material is to be included in the calculation of the inertia of the section, and the lever y is to be measured from the neutral axis to the top of keel and to the moulded deck line at side. Lightening holes in girders need not be deducted, provided their depth does not exceed 20 per cent of the depth of the girder web. Scallops and isolated drain holes need not be deducted.

In general, isolated deck openings outside the line of hatches need not be deducted, but local compensation may be required—see D 407.

308 Where continuous hatch coamings are arranged, 80 per cent of the area of the continuous hatch coamings may be included in the calculation of the section modulus and the lever y is to be measured:—

(a) to the moulded deck line at side amidships,

(b) to a point a distance above the moulded deck line at side amidships equal to the height of the hatch coaming above the deck.

The modulus with y measured as in (a) is to be 5 per cent greater than required by 301, and with y measured as in (b) may be 10 per cent less than required by 301.

309 Where two or more hatchways are arranged abreast, the percentage of the material between hatchways to be included in the section modulus will be decided in each case. Similar consideration will be given to other special designs.

310 When an erection is fitted the required modulus is to be determined in accordance with D 16. The required upper deck area clear of the erection is to extend to at least a distance equal to 0,04L inside the erection at each end.

or in British units:-

TABLE D 3.1-VALUES OF K

LENGTH L	K	Difference in K per 1 ft difference in L	LENGTH L	K	Difference in K per 1 ft difference in L	LENGTH L	К	Difference in K per 1 ft differenc in L
Feet			Feet		0.0019	Feet		0.0031
300	0.121	0.0011	540	0.456	0.0000	780	1.067	
310	0.132	0.0011	550	0.476	0.0020	790	1.099	0.0032
	0.102	0.0011		0 110	0.0020			0.0032
320	0.143	0.0011	560	0.496	0.0000	800	1.131	0.0000
330	0.154	0.0011	570	0.516	0.0020	810	1.164	0.0033
		0.0011			0.0021			0.0033
340	0.165	0.0010	580	0.537	0.0007	820	1.197	0.0004
350	0.177	0.0012	590	0.558	0.0021	830	1.231	0.0034
	0.411	0.0012	000	0 000	0.0022	000	1 201	0.0034
360	0.189	0.0010	600	0.580	0.0000	840	1.265	0.0004
370	0.201	0.0012	610	0.602	0.0022	850	1.299	0.0034
	0 401	0.0012	010	0 002	0.0023	000	1 200	0.0035
380	0.213	0.0010	620	0.625	0.0000	860	1.334	0.000*
390	0.225	0.0012	630	0.648	0.0023	870	1.369	0.0035
	0 220	0.0012	000	0 010	0.0024	0.0	1 000	0.0035
400	0.237		640	0.672		880	1.404	
410	0.249	0.0012	650	0.697	0.0025	890	1.439	0.0035
***	0 210	0.0013	000	0 001	0.0026	000	1 100	0.0035
420	0.262		660	0.723		900	1.474	
430	0.275	0.0013	670	0.749	0.0026	910	1.509	0.0035
100	0 210	0.0014	010	0 110	0.0027	310	1 000	0.0035
440	0.289		680	0.776		920	1.544	0.0000
450	0.303	0.0014	690	0.803	0.0027	930	1.579	0.0035
200	0.000	0.0015	030	0.009	0.0028	300	1.010	0.0035
460	0.318		700	0.831		940	1.614	
470	0.334	0.0016	710	0.859	0.0028	950	1.649	0.0035
	0.001	0.0016	710	0 000	0.0028	300	1 010	0.0036
480	0.350		720	0.887		960	1.685	
490	0.366	0.0016	730	0.916	0.0029	970	1.721	0.0036
700	0.900	0.0017	100	0.910	0.0029	310	1.121	0.0036
500	0.383		740	0.945		980	1.757	
510	0.400	0.0017	750	0.975	0.0030	990	1.793	0.0036
010	0.400	0.0018	700	0.910	0.0030	330	1.199	0.0037
520	0.418		760	1.005		1000	1.830	
530	0.497	0.0019	770	1,026	0.0031			
930	0.437	0.0019	770	1.036	0.0031			

Section 3A

CARRIAGE OF ORE CARGOES

Longitudinal Strength

1 The following requirements are applicable to the Class 100A1 ore carrier, or for the notations "Strengthened for Ore Cargoes", "Strengthened for Ore Cargoes—Specified holds may be empty" and "Strengthened for Ore Cargoes—Specified holds may be empty, or Oil Cargoes".

2 The section modulus at deck and keel is not to be less than the greatest of the following values:—

(b)
$$\frac{M_{O}}{3} + 104 \, \text{SWBM}_{L} \, \text{cm}^{3}$$

(c)
$$\frac{0.85\,\mathrm{M_{1}}}{2.7} + 92\,\mathrm{SWBM_{B}}\,(\mathrm{C_{b1}} + 0.20)\,\mathrm{cm^{3}}$$

where
$$M_O = 0.90 \text{ K B } (C_D + 0.70) \times 10^5$$
,

$$M_1 = 0.90 \text{ KB} (C_{b1} + 0.70) \times 10^5,$$

K is to be determined from Table D 3.1,

C_b = the moulded block coefficient at load draught or 0,045 L, whichever is the greater, but is not to be taken as less than 0,60. The block coefficient is to be determined using the length L as defined in D 201,

C_{b1} = the moulded block coefficient at the ballast or part loaded draught but is not to be taken as less than 0,60. The block coefficient is to be determined using the length \(\Lambda \) as defined in D 201. (See also D 103),

B = the moulded breadth, in metres,

SWBM_L = the maximum still water bending moment, in tonnes metres, hogging or sagging in loaded conditions,

SWBM_B = the maximum still water bending moment, in tonnes metres, hogging or sagging in ballast or part loaded conditions (departure and arrival).

or in British units:-

(a)
$$M_O in^2 ft$$

(b)
$$\frac{M_O}{3} + \frac{SWBM_L}{6 \cdot 1} in^2 ft$$

(c)
$$\frac{0.85 \text{ M}_1}{2.7} + \frac{\text{SWBM}_B (C_{b1} + 0.20)}{6.9} \text{ in}^2 \text{ft}$$

where
$$M_0 = 0.90 \text{ K B } (C_b + 0.70) \times 10^3$$

$$M_1 = 0.90 \text{ K B } (C_{b1} + 0.70) \times 10^3,$$

K is to be determined from Table D 3.1,

C_b = the moulded block coefficient at load draught or 0.045L, whichever is the greater, but is not to be taken as less than 0.60. The block coefficient is to be determined using the length L as defined in D 201,

C_{D1} = the moulded block coefficient at the ballast or part loaded draught but is not to be taken as less than 0.60. The block coefficient is to be determined using the length L as defined in D 201. (See also D 103).

B = the moulded breadth, in feet,

SWBM_L = the maximum still water bending moment, in tons feet, hogging or sagging in loaded conditions,

SWBM_B = the maximum still water bending moment, in tons feet, hogging or sagging in ballast or part loaded conditions (departure and arrival).

Note. When the required modulus is M_O, the maximum associated still water bending moment in loaded conditions will be:—

 $6.4~{\rm M}_{\odot} \times 10^{-3}$ tonne m (4.08 ${\rm M}_{\odot}$ ton ft) which corresponds to a stress of $6.4~{\rm kg/mm^2}$ (4.08 ton/in²).

Section 4

DECK PLATING

Symbols

401 L = length of ship, in metres (feet).

L_I = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft).

S = spacing of beams or longitudinals, in mm (in).

Construction

402 Provision is made for longitudinal or transverse framing at all decks, but for ships exceeding 120 m (395 ft) in length, longitudinal framing is, in general, to be adopted at the strength deck.

STRENGTH DECK

403 The thickness of strength deck plating amidships outside the line of openings is to be that necessary to give the section modulus required by D 3 or D 3A, but it is not to be less than:—

- (a) Longitudinal framing $\frac{8}{100} \left(1 + \frac{L}{305}\right) \text{mm}$
- (b) Transverse framing $\frac{s}{90} \left(1 + \frac{L}{305}\right) mm$

(s is not to be taken as less than $\frac{L_1}{0.6} + 510$ mm except when the actual spacing is considerably less than this value).

Inside the line of openings, the thickness amidships is not to be less than:—

(c) Longitudinal or transverse framing $6.5 + \frac{L}{48}$ mm for a spacing not exceeding $\frac{L_1}{0.6} + 650$ mm

or in British units:-

- (a) Longitudinal framing $\frac{s}{100}$ $\left(1 + \frac{L}{1000}\right)$ in
- (b) Transverse framing $\frac{s}{90} \left(1 + \frac{L}{1000}\right)$ in

(8 is not to be taken as less than $\frac{L_1}{50} + 20$ in except when the actual spacing is considerably less than this value).

Inside the line of openings, the thickness amidships is not to be less than:—

(c) Longitudinal or transverse framing $0.255 + \frac{L}{4000}$ in for a spacing not exceeding $\frac{L_1}{50} + 25.5$ in.

For grades of steel, see 410.

The midship thickness outside line of openings is to be maintained for 0,4L amidships and is to be tapered gradually to the end thickness.

End Thickness

404 The thickness of deck plating for 0,1L from the ends is not to be less than $6 + \frac{L}{48} \text{mm} \left(0.235 + \frac{L}{4000} \text{ in}\right)$.

Superstructures

405 When an erection is fitted amidships, the required strength deck plating thickness clear of the erection should extend within the erection as required by D 310. The plating thickness within the erection is to be determined as follows:—

- (a) If erection efficiency factor (see D 16) = 0 then the thickness should be derived from 403.
- (b) If erection efficiency factor = 1,0 then the thickness should be derived from 412 for second, third or platform deck as appropriate to the number of erection decks above.
- (c) For intermediate values of erection efficiency factor, the minimum thickness should be obtained by interpolation.

406 For increases to thickness of deck plating in way of ends of superstructures, see D 1715.

Deck Openings

407 Openings in the strength deck outside line of openings should be kept to a minimum and are to be arranged clear of main hatch corners.

Openings in the strength deck forward of a midship bridge between hatch and bridge front and adjacent to a hatch corner are to be avoided so far as possible. If they are essential, special consideration is to be paid to their design and Grade E steel may be required in these regions.

Compensation is not required for elliptical or circular deck openings in the strength deck situated within 0,5L amidships when the breadth of opening does not exceed 10 per cent of the distance between the hatch side and the ship's side, but:—

- (a) Elliptical openings are to have the major axis fore and aft and the ratio of length to breadth of the opening is not to be less than 2:1.
- (b) Circular openings are to be reinforced as required by 408.

Where elliptical or circular openings in strength deck and within 0,5L amidships have a breadth greater than that given above, compensation is to be provided for the excess breadth of opening. The compensating area is normally to be provided by increasing the deck thickness. In addition, circular openings are to be reinforced as required by 408.

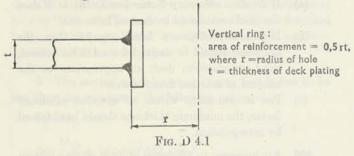
Full compensation is to be provided for openings of other shapes within 0.5L amidships.

Outside 0.5L amidships compensation is not, in general, required except for openings at the break of a poop.

The above requirements also apply generally to openings in lower decks but the breadth before compensation is required may be 15 per cent and edge reinforcement to circular openings is not required where their breadth does

not exceed 10 per cent of the distance between the hatch side and the ship's side.

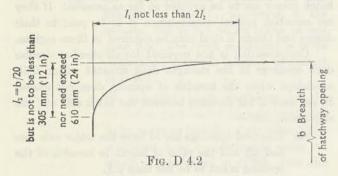
408 Where circular holes in the strength deck are required to be reinforced (see 407), this is generally to be arranged as shown in Fig. D 4.1, but alternative arrangements for edge reinforcement will be considered.



409 Where the corners of large openings in the strength deck are parabolic or elliptic, insert plates are not required.

If elliptical corners are arranged, the major axis should be fore and aft, the ratio of the major to minor axis should not be less than 2:1, and the minimum half-length of the major axis is to be as defined by I, in Fig. D 4.2.

Where parabolic corners are arranged, the dimensions should be as shown in Fig. D 4.2.



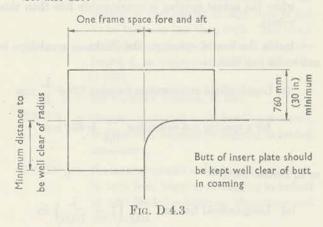
Where two or more hatchways are arranged abreast, the corner arrangements will be considered.

For other shapes of corner, insert plates of the size and extent shown in Fig. D 4.3 will be required.

Required thickness of insert plate:-

Thickness of insert is to be 5 mm (0·20 in) greater than deck thickness up to deck thickness of 25,5 mm (1·00 in). At a deck thickness of 38 mm (1·50 in) and above the increase is to be 4 mm (0·15 in). Between 25,5 and 38 mm (1·00 and $1\cdot50$ in), the increase is to be obtained by interpolation.

See also 419.



Grades of Steel

410 Steel of Grades B and D will generally be required for the strength deck as shown in Table D 4.1.

411 In general, any deck plate at a hatch corner exceeding 35,5 mm (1·4 in) in thickness is to be Grade E or EH steel.

TABLE D 4.1

THICKNESS OF PLATING	GRADE OF STEEL
Greater than 20,5 mm (0·8 in) but not exceeding 25,5 mm (1·0 in)	B (i) For 0,4L amidships (ii) At corners of openings and at breaks of superstructures irrespective of position.
Exceeding 25,5 mm (1·0 in)	D (i) For 0,4L amidships (ii) At corners of openings and at breaks of superstructures irrespective of position (iii) Any stringer plating irrespective of position.

See also 422 for refrigerated ships, D 1917 for topside tanks, and D 6519 for higher tensile steel.

LOWER DECKS

412 The thickness of plating is not to be less than that given below:—

Second deck—outside line of openings and within 0,4L amidships
$$\dots \frac{s}{85}$$
 mm (in)

Second deck—within line of openings and for 0,1L at ends
$$\dots \frac{s}{100}$$
 ,, ,,

Third deck—within line of openings and for
$$0.1L$$
 at ends ... $\frac{s}{100}$,, ,,

Platform decks
$$\frac{s}{100}$$
 ,, ,,

The value of S for use in the above formulæ is not to be taken as less than $\frac{L_1}{0.6} + 510 \text{ mm} \left(\frac{L_1}{50} + 20 \text{ in}\right)$.

Consideration will be given when the actual spacing is considerably less than this value.

Where a deck loading exceeding 4,4 tonne/m² (0·4 ton/ft²) is contemplated, the thickness of the deck plating will be considered.

413 Where long wide hatchways are arranged on lower decks, it may be necessary to increase the deck thickness obtained from 412 to ensure effective support for side framing.

414 Deck plating forming the upper flange of underdeck girders is to have a thickness in mm (in) not less than:—

$$\sqrt{\text{girder face area (cm}^2)}$$
 $\sqrt{\frac{\text{girder face area (in}^2)}{180}}$

and 10 per cent greater than this for hatch side girders. The width of the increased plate is not to be less than 760 mm (30 in).

415 The arrangements at hatch corners in second decks are to be in accordance with 409 except that the thickness of the insert (if required) may be 2,5 mm (0·10 in) greater than the deck thickness.

416 For grades of steel in refrigerated ships, see 422.

GENERAL

Deck Loading

417 For permissible deck loading appropriate to Rule scantlings and for scantlings for specific loading, see D 25.

See also 425 and 426.

Fork Lift Trucks

418 If provision is to be made for the use of fork lift trucks, it is recommended that the deck thickness should not be less than that given in Table D 4.2.

If fork lift trucks are to be used on insulated decks or tank tops, consideration will be given to the permissible loading in association with the insulation arrangements and the plating thickness.

TABLE D 4.2

TYPE OF TRUCK	TOTAL WEIGHT OF TRUCK AND LOAD Tonnes/Tons											
	3	4	5	6	7	8	9	10	11	12	13	14
	MINIMUM DECK THICKNESS (irrespective of beam or longitudinal spacing) mm (in)											
Two wheels at fork end	7,5 (0·30)	9,0 (0·35)	10,0 (0.40)	11,0 (0·44)	12,0 (0·47)	12,5 (0·50)	13,5 (0·53)	14,0 (0·55)	15,0 (0·59)	15,5 (0·61)	16,0 (0·63)	16,5 (0·65)
Four wheels in pairs at fork end	6,5 (0·26)	7,5 (0·30)	8,0 (0·32)	9,0 (0·35)	9,5 (0·38)	10,5 (0·41)	11,0 (0·44)	11,5 (0·46)	12,0 (0·47)	12,5 (0·50)	13,0 (0·51)	13,5 (0·53)

Structural Details

419 Attention is to be paid to structural continuity. Abrupt changes of shape or section and sharp corners are to be avoided. The plating at corners of all openings in strength decks is to be well rounded and free from notches. (See also 407 and 409.)

Where the deck is connected to the main hatchway coamings by welding, the deck opening and the coamings at the corners of the hatchways are to be rounded with a radius which, for openings within 0.6L amidships, is not to be less than $2\frac{1}{4}$ of the breadth of the opening; the minimum radius at all main hatchways in the strength deck is to be 150 mm (6 in).

If the deck plating extends inside the coamings the arrangements may be as in the preceding sub-paragraph, or the coamings may be square at the corners, provided that:—

- (a) within 0,6L amidships, the side coamings are extended in the form of a tapered bracket, and,
- (b) the openings in the deck plating at the corners are elliptic or parabolic, or are rounded with a radius which, for openings within 0,6L amidships, is not to be less than ¹/₂₄ of the breadth of the opening with a minimum of 305 mm (12 in), and for openings forward or abaft this region is to be a minimum of 150 mm (6 in).

Where the deck plating stops at the coaming and is welded thereto, through penetration welds are to be used. Where the deck plating extends inside the coaming, the free edges of the plating in way of the hatchways are to be smooth and free of weld attachments.

Arrangements at the welded corners of machinery casings will be considered.

Sheathed Decks

420 Where plated decks are sheathed with wood or approved composition, the minimum thicknesses given in 403, 404 and 412 may be reduced by 10 per cent for a 50 mm (2 in) sheathing thickness or 5 per cent for 25,5 mm (1 in), with intermediate values in proportion.

The steel deck is to be coated with a suitable material in order to prevent corrosive action and the sheathing or composition is to be effectively secured to the deck. (See also F 807 and F 1003.)

Water Testing

421 Weather decks, where riveted, are to be caulked and hose tested on completion.

Refrigerated Ships

422 If the temperature of the steel of the deck can fall to the values given in Table D 4.3 the grade of steel for the following items shall comply with the requirements of the Table:—

Deck plating, webs of deck girders,
Longitudinal bulkhead strakes attached to the deck,
Hatch coaming shelf plates and their face bars.

423 For the purposes of 422, the temperature to which the steel deck may be reduced is to be assessed as follows:—

Arrangement

- Deck not covered with insulation in the refrigerated space.
- Deck covered with insulation in the refrigerated space and not insulated on the other side.
- Deck covered with insulation on both sides.

Deck Temperature

Temperature of the refrigerated space.

Temperature of the space on the uninsulated side.

- (a) Mean of the temperatures of the spaces above and below the deck provided the difference in the temperatures is not more than 11 degC (20 degF).
- (b) Mean of the temperatures of the spaces above and below the deck less 3 degC (5 degF) if the difference in the temperature is more than 11 degC (20 degF) but not more than 33 degC (60 degF).
- (c) When the temperature difference is more than 33 degC (60 degF) the deck temperature will be specially assessed.

When one of the spaces concerned is not refrigerated, the temperature of that space is to be taken as 5°C (41°F).

Deep Tank

424 For minimum thickness of plating of a deck forming the crown of tank, see D 1919.

Carriage of Timber on Strength Deck

425 Ships to which a timber load line is assigned are to be specially strengthened (see D 808 and D 1319) and Owners are referred to the Load Line Convention for the permissible height of timber deck cargo.

TABLE D 4.3

TEMPERATURE (see D 423)	GRADES OF STEEL OR CHARPY V-NOTCH IMPACT TEST REQUIREMENTS FOR STEEL					
DOWN TO	Strength deck within 0,5L amidships	Strength deck at ends and second and lower decks				
0°C (32°F) -5°C (23°F) -10°C (14°F) -20°C (-4°F)	A (Note 1) D (Note 1) E E E 6,2 kg m (45 ft lb)	A (Note 1) D (Note 1) D (Note 1) E				
−30°C (−22°F)	Minimum average impact energy at temperature concerned (Note 3)	E (Note 2)				
below -30°C (—22°F)	"	4,8 kg m (35 ft lb) Minimum average impact energy at temperature concerned (Note 3)				

Notes

- 1. Subject to overriding requirements for special steels in other Sections of the Rules.
- Subject to thickness not exceeding 15 mm (0·6 in). Requirements for greater thicknesses will be subject to special consideration.
- 3. See Table P 2.2 for minimum average impact energy values for subsidiary Charpy V-notch test[pieces.

Concentrated Loading

426 Additional strengthening to the decks may be required where there is indication of concentration of loading.

Higher Tensile Steel

- 427 When higher tensile steel is used, the scantlings are to be determined in accordance with D 65.
- 428 When higher tensile steel is used amidships and mild steel at the ends, the taper line for the mild steel is to be determined using a nominal mild steel midship thickness of:—
 - (a) higher tensile thickness/k or, if the higher tensile steel thickness is based upon minimum thickness requirements:—
 - (b) the minimum mild steel thickness determined from 403.

The higher tensile steel thickness, outside the midship 0,4L, is to be based upon a taper line from the midship thickness at 0,2L aft or forward of amidships to any point on the mild steel taper line.

Section 5

SHELL PLATING

Symbols

501

- L = length of ship, in metres (feet).
- L₁ = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft).
- D = moulded depth, in metres (feet), to the uppermost continuous deck. In way of a superstructure not less than 0,15 L in length, D may be taken to the superstructure deck.
- B = moulded breadth, in metres (feet).
- d = moulded draught, in metres (feet), but
 need not be taken as greater than:—
 - $\frac{L}{15}$ when L does not exceed 135 m (443 ft),
 - $\frac{\mathsf{L}}{30}$ +4,5 when L exceeds 135 m
 - $\left(\frac{\mathsf{L}}{30} + 14.77 \text{ when } \mathsf{L} \text{ exceeds 443 ft}\right)$
- S = spacing of frames or longitudinals, in mm (in).
- S = spacing of floors or transverses, in metres (feet).

General

502 Provision is made for longitudinal or transverse framing for the bottom and side shell, but for ships exceeding 120 m (395 ft) in length, longitudinal framing is, in general, to be adopted at the bottom.

Keel

503 The width and thickness of the keel over the whole length are not to be less than the values derived from the following formulæ, nor is the thickness to be less than that of the adjacent shell plating.

Width = 70B mm (0.84B in) but need not exceed 1800 mm (71 in)

Thickness =
$$6 + \frac{L_1}{10} \, \text{mm} \, \left(0.235 + \frac{12L_1}{10000} \, \text{in} \right)$$

For grades of steel, see 512 and 513.

Bottom Shell

504 The thickness of bottom shell plating amidships to the upper turn of bilge is to be that necessary to give the section modulus required by D 3 or D 3A, but is not to be less than:—

(a) Longitudinal framing ...
$$\frac{s}{3000}$$
 (L₁ + 75) $\sqrt{\frac{d}{L_1}}$ mm

(b) Transverse framing ...
$$\frac{s}{3000}$$
 (L+165) $\sqrt{\frac{d}{L}}$ mm

Where, in a ship with longitudinal bottom stiffening, the bilge strake is stiffened transversely the thickness of this strake is to be as given by the following formula, but need not exceed that of the bottom or side shell, whichever is the greater:—

(c)
$$\frac{s}{3450}$$
 (L₁ + 165) $\sqrt{\frac{d}{L_1}}$ mm

(In (a), (b) and (c) S is not to be taken as less than $\frac{L_1}{0,6} + 510$ mm, except when the actual spacing is considerably less than this value.)

or in British units:-

(a) Longitudinal framing ...
$$\frac{s}{9.84} \left(\frac{L_1 + 246}{1000} \right) \sqrt{\frac{d}{L_1}}$$
 in

(b) Transverse framing ...
$$\frac{s}{9.84} \left(\frac{L + 541}{1000}\right) \sqrt{\frac{d}{L}}$$
 in

Where, in a ship with longitudinal bottom stiffening, the bilge strake is stiffened transversely the thickness of this strake is to be as given by the following formula, but need not exceed that of the bottom or side shell, whichever is the greater:—

(c)
$$\frac{s}{11 \cdot 32} \left(\frac{L_1 + 541}{1000} \right) \sqrt{\frac{d}{L_1}}$$
 in

(In (a), (b) and (c) S is not to be taken as less than $\frac{L_1}{50} + 20$ in, except when the actual spacing is considerably less than this value.)

Where the bilge is stiffened longitudinally the thickness is to be determined from (a) above with an equivalent spacing S₁ as determined from D 4304.

The midship thickness is to extend over 0,4L amidships and is to be tapered gradually to the end thickness.

For grades of steel, see 512 and 513. For strengthening of bottom forward, see D 10. For transversely framed ships, see also 515.

Side Shell

 $505\,$ The thickness of side shell plating amidships is to be not less than:—

$$t = \frac{s + 150}{640} \sqrt{\frac{\text{d L}}{D}} \text{ mm}$$

but in no case is to be less than that required by 508.

(d is not to be taken as less than $\frac{L_1}{20}$ and 8 not less than 559+1,11 L mm or 865 mm, whichever is the lesser.)

Where the side shell is framed longitudinally, S is to be the spacing of longitudinals reduced by $100\left(1-\frac{250\text{S}}{\text{S}}\right)$ mm, except when $100\left(1-\frac{250\text{S}}{\text{S}}\right)$ is negative,

or in British units:-

$$t = \frac{s+6}{1160} \sqrt{\frac{d L}{D}} \text{ in}$$

but in no case is to be less than that required by 508.

(d is not to be taken as less than $\frac{L_1}{20}$ and S not less than $22 + \frac{L}{75}$ in or 34 in, whichever is the lesser.)

Where the side shell is framed longitudinally, S is to be the spacing of longitudinals reduced by $4-\frac{12S}{S}$ in, except when $4-\frac{12S}{S}$ is negative.

The midship thickness is to extend over 0,4L amidships and is to be tapered gradually to the end thickness. The thickness may have to be increased to comply with 507.

The thickness of side shell need not exceed that determined from 504(a) or (b) using the spacing of side shell frames or longitudinals.

506 Where the shear force has to be investigated (see D 303), the shear stress at the neutral axis is to be calculated as:—

$$\frac{100 \text{F A}\overline{\text{y}}}{\text{I t}} \text{ kg/mm}^2 \left(\frac{\text{F A}\overline{\text{y}}}{12 \text{ I t}} \text{ ton/in}^2 \right)$$

where F = shear force in still water, in tonnes (tons), taking into account local forces at transverse bulkheads, where applicable. (See D 941),

 $A\overline{y}$ = first moment of area of the longitudinal material above the neutral axis, in cm³ (in²ft),

I = moment of inertia of the transverse section in cm⁴ (in² ft²),

t = combined thickness, in mm (in), of side shell and longitudinal bulkheads, if fitted, for both sides of the ship, at the neutral axis.

Note. The values of $A_{\overline{y}}$ and I for the midship section may be used for the calculation of the shear stress at any point along the length of the ship.

507 If the shear stress at any point along the ship's length exceeds the value derived from Table D 5.1, then the side shell in way is to be increased in thickness or, where specially approved, stiffened by intermediate frames.

TABLE D 5.1

STATION	SHEAR STRESS	STATION	SHEAR STRESS
AP 1 1 1 2 2 2 2 2 4 4 4 4 2 2	kg/mm ² (ton/in ²) 8,25 (5·23) 7,81 (4·95) 7,37 (4·68) 6,93 (4·40) 6,66 (4·24) 6,49 (4·13) 6,60 (4·18) 6,82 (4·35) 7,26 (4·62) 7,81 (4·95) 8,25 (5·23)	5½ 6 6½ 7 7½ 8 8½ 9 9½ FP	kg/mm ² (ton/in ²) 7,65 (4·84) 7,21 (4·57) 6,77 (4·29) 6,49 (4·13) 6,49 (4·13) 6,66 (4·24) 7,04 (4·46) 7,54 (4·79) 7,98 (5·06) 8,25 (5·23)

End Thickness

508 The thickness of shell plating for 0,075L from the ends is not to be less than:—

$$\left(6.5 + \frac{L}{30}\right)\sqrt{\frac{s}{s_b}} \; mm \quad \left(\left(0.255 + \frac{L}{2500}\right)\sqrt{\frac{s}{s_b}} \; in\right)$$

where S_D = standard frame spacing, in mm (in), as given in D 705 and D 706.

Sheerstrake

509 The width of sheerstrake amidships is not to be less than 150D mm (1.8D in), but need not exceed 2135 mm (84 in), and the thickness is not to be less than that of the deck plating or the side shell, whichever is the greater.

At ends, the thickness may be the same as the side shell, but provided the draught does not exceed 0.7D (D being measured to the uppermost continuous deck) the end thickness may be as required for a poop or forecastle.

For increase in thickness at ends of superstructure, see D 1715.

510 The upper edge of the sheerstrake is to be dressed smooth and kept free of isolated welded fittings or connections. Bulwarks are not to be welded to the top of the sheerstrake within 0,5L amidships. In ships over 150 m (492 ft) in length, scupper openings are not to be cut above the deck within 0,5L amidships or in way of breaks of superstructures.

511 Where a rounded sheerstrake is adopted, the radius should, in general, not be less than 15 times the thickness. Where Grade E plates are subjected to severe cold working, or where local heating of the plating is adopted, it may be necessary to require re-normalizing of the plate. The welding of fairleads or other fittings to this plate is to be kept to a minimum and details are to be submitted.

Grades of Steel

512 In ships between 105 and 135 m (344·5 and 443 ft) in length, the sheerstrake for 0·4L amidships is generally to be Grade B for thicknesses up to and including 20,5 mm (0·8 in) and Grade D for thicknesses in excess of 20,5 mm (0·8 in).

Elsewhere, Grade B will generally be required when the thickness is greater than 20,5 mm (0·8 in) but does not exceed 25,5 mm (1·0 in), and Grade D will generally be required when the thickness exceeds 25,5 mm (1·0 in) as follows:—

(a) Bottom shell to upper turn of bilge:—0.3L amidships when the length is 155 m (508 ft) and below, and 0.4L amidships when the length is 215 m (705 ft) and above, with intermediate values obtained by interpolation.

Where the bottom plating is required to be of Grade B or D, the keel plate is to be of the same Grade.

- (b) Sheerstrake:-
 - (i) 0.4L amidships.
 - (ii) at the poop front and at the ends of the bridge.
 - (iii) outside the limits given in (i), when the thickness exceeds 25,5 mm (1.0 in).

See also D 6519 for higher tensile steel.

513 In general, strakes of Grade E steel are to be arranged as follows:—

LENG	TH L	
OVER	NOT EXCEEDING	GRADE E STRAKES
metres (feet) 135 (443) 170 (558) 200 (656)	metres (feet) 170 (558) 200 (656)	Sheerstrake (see Note 1) Sheerstrake Sheerstrake Bilge strake Keel (see Note 2)

- Notes. 1. In ships between 135 and 170 m (443 and 558 ft) in length, the sheerstrake may be Grade D provided the deck plating is also Grade D.
 - 2. In ships exceeding 200 m (656 ft) in length, the keel may be Grade D provided the bottom plating is also Grade D.

The Grade E strakes are to extend over 0,4L amidships.

The breadth of each strake is not to be less than 1500 mm (60 in), except that the bilge strake shall not be less than 1800 mm (71 in) and the keel shall be as required by 503.

Openings in Sheerstrake or Shell Plating

514 Cargo door openings are to have well rounded corners. A plan of structure in way of doors indicating proposed compensation is to be submitted for approval.

Sea inlets, or other openings, are to have well rounded corners and, so far as possible, should be kept clear of the bilge radius. Openings on, or near to, the bilge radius should be elliptical. The thickness of sea inlet boxes should be the same as the adjacent shell, but not less than 12.5 mm (0.50 in).

In general, compensation will not be required for holes in the sheerstrake which are clear of any deck openings outside the line of the main hatchways, and whose depth does not exceed 20 per cent of the depth of the sheerstrake or 380 mm (15 in), whichever is the lesser.

Local Stiffening of Bottom Shell

515 In ships with all-welded, transversely framed bottom construction, additional longitudinal stiffeners are to be fitted for 0.4L amidships.

Local Strengthening

516 The thickness of plates connected to the stern-frame or propeller brackets is not to be less than 50 per cent greater than that required for shell at ends.

Plating in way of hawsepipe is to be suitably increased. For strengthening for navigation in ice, see D 24.

Bilge Keels

517 Where bilge keels are fitted, it is desirable that they be attached to a continuous flat bar which may be welded to the shell. Scallops are to be arranged at welded butts in the flat bar, or alternatively, a 25,5 mm (1 in) hole should be drilled in the butt weld just above the fillet weld; in this case, the fillet weld is to be continuous.

Alternative arrangements, or arrangements omitting the flat bar, will be considered.

Bilge keels are to be gradually tapered at their ends and are not to finish on an unstiffened panel.

Higher Tensile Steel

- 518 'When higher tensile steel is used, the scantlings are to be determined in accordance with D 65.
- 519 When higher tensile steel is used amidships and mild steel at the ends, the taper line for the mild steel is to be determined using a nominal mild steel midship thickness of:—
 - (a) higher tensile thickness/k or, if the higher tensile steel thickness is based upon minimum thickness requirements:—
 - (b) the minimum mild steel thickness determined from 504.

The higher tensile steel thickness, outside the midship 0,4L, is to be based upon a taper line from the midship thickness at 0,2L aft or forward of amidships to any point on the mild steel taper line.

Section 6

LONGITUDINAL FRAMING

Symbols

601 L = length of ship, in metres (feet).

L₁ = length of ship, in metres (feet), but need not to be taken as greater than 215 m (705 ft). (See also line 8, Table D 6.1).

d = moulded draught, in metres (feet).

S = spacing of longitudinals, in mm (in).

S = span of longitudinals, in metres (feet).

D = moulded depth, in metres (feet), to the uppermost continuous deck.

H = height from tank top to deck at side amidships, in metres (feet).

Weather Decks

602 The section modulus of weather deck longitudinals is not to be less than:—

$$\frac{I}{V} = \frac{K_1 \, s \, h}{100} + \frac{K_2 \, s}{100} \left(\frac{S \, L_1}{100}\right)^2 \, cm^3$$

$$\left(\frac{I}{y} = \frac{\mathsf{K_1} \; s \; h}{100} + \frac{\mathsf{K_2} \; s}{100} \; \left(\frac{S \; \mathsf{L_1}}{1000}\right)^2 \; \mathrm{in}^3\right)$$

where K1, K2 and h are taken from Table D 6.1.

603 If the longitudinals carry hanging cargo, such as chilled beef, the modulus determined from 602 is to be increased by 50 per cent if the height of the 'tween deck below is 2,6 m (8.5 ft) or less, and 100 per cent if the height is 3,2 m (10.5 ft) (with intermediate heights in proportion) but the modulus need not exceed that derived from 605 for a 2,6 m (8.5 ft) 'tween deck height above. No increase is required if the modulus derived from 605 is less than that derived from 602.

Cargo and Accommodation Decks

604 The section modulus of cargo and accommodation deck longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{K s L_1 + 25 h s S^2}{10000} cm^3$$

$$\left(\frac{1}{y} = \frac{K \ s \ L_1 + 1 \cdot 1 \ h \ s \ S^2}{10000} \operatorname{in}^3\right)$$

where K = 5.9 (2.8) for cargo decks,

5,1 (2.4) for accommodation decks.

h = load height in metres (feet) as given in D 809.

Where fork lift trucks are to be used on the deck, the section modulus of longitudinals is not to be less than required by D 811, taking S and S in the formula as defined in 601, or the value derived above or by 605 if appropriate, whichever is the greater.

For permissible deck loading appropriate to Rule scantlings and for scantlings for specific loadings, see D 25.

605 If cargo deck longitudinals carry hanging cargo such as chilled beef, and may be simultaneously loaded above with cargo, the modulus is to be determined from 604 with h increased by 0,76 m (2.5 ft) if the height of the 'tween deck below is 2,6 m (8.5 ft) or less and 2,29 m (7.5 ft) if the height is 3,8 m (12.5 ft) (with intermediate heights in proportion). A similar addition is to be made, if appropriate, to accommodation deck longitudinals.

Bottom Longitudinals

606 The section modulus is not to be less than:-

$$\frac{1}{y} \, = \! \frac{\text{s d } (\text{S} + 3,\!05)^2 \, \sqrt{\text{L}_1 + 380} \, \text{cm}^3}{11\,500}$$

$$\left(\frac{I}{y} = \frac{\text{s d (S} + 10)^2 \sqrt{L_1 + 1250}}{475\,000} \text{ in}^3\right)$$

607 The unsupported span of the longitudinals is not to exceed 2,5 m (8·2 ft). With longer spans, struts having scantlings derived from D 918 with Z taken as the modulus of the bottom longitudinal given by 606 are to be fitted, except when a notation regarding the carriage of heavy cargoes is to be assigned. In this case, the spacing of floors is not to exceed 2,5 m (8·2 ft). The scantlings of the longitudinals adjacent to the centre girder and the margin plate may be based on a span of 1,25 m (4·1 ft).

Inner Bottom Longitudinals

608 Class 100A1 without notations.

The section modulus is not to be less than 85 per cent of the values calculated from 606.

609 "Strengthened for Heavy or Ore Cargoes" notation.

The section modulus of rolled sections is not to be less than 85 per cent of the bottom longitudinals nor less than:—

$$\frac{I}{V} = \frac{S^2 \ S \ H}{77} \ cm^3 \qquad \left(\frac{I}{V} = \frac{S^2 \ S \ H}{1755} \ in^3\right)$$

If plate girders are fitted alternately with rolled sections, the section modulus, as determined above, may be reduced by 10 per cent. The girders are to have a thickness derived from D 927.

TABLE D 6.1

LINE	LOCATION OF WEATHER DECK LONGITUDINAL	K ₁	K ₂	h (metres (feet))
1	0,4L amidships outside line of openings (See Note 2)	5,70 (2·7)	0.72 (0·96)	1010015
2	At 0,12L from F.P. outside line of openings		0,62 (0·83)	1,2+2,04E (4+6.7E) but not less than
3	At and abaft 0,1L from A.P.	4,00 (1·9)	0,50 (0·67)	1,2 (4·0) nor greater than 1,5 (5·0)
4	Abaft 0,12∟ from F.P. within line of openings	4,00 (1·9)	0,50 (0·67)	(See Note 3)
5	Between 0,12L and 0,075L from F.P. outside and inside line of openings	5,70 (2·7)	0,72 (0·96)	1,5 (5.0)
6	Forward of 0,075L from F.P. outside and inside line of openings	6,35 (3·0)	0,78 (1·04)	1,8 (6.0)
7	Bridge where forming an effective super- structure	6,75 (3·2)	0,72 (0·96)	0,9+2,04E (3+6·7E)
8	Short bridge or poop (L ₁ for short bridge or poop need not be taken as greater than 153 m (502 ft))	4,65 (2·2)	0,50 (0·67)	0,9 (3.0) nor greater than 1,2 (4.0)

Notes. 1.
$$E = \frac{0.0914 + 0.003L}{D-d} - 0.15$$

 $\left(E = \frac{0.3 + 0.003L}{D-d} - 0.15 \text{ British}\right)$

- 2. The amidship scantlings of longitudinals as determined from Line 1 may be tapered to the values determined from Lines 2 and 3.
- 3. For decks above the uppermost continuous deck, h obtained from the formula for lines 1 to 4 can be successively reduced by 0,31 m (1.02 ft) for each deck to a minimum of 0,45 m (1.48 ft).

610 "Strengthened for Heavy or Ore Cargoes— Specified Holds may be Empty" notation.

The section modulus of rolled sections is not to be less than:—

$$\frac{I}{V} = \frac{S^2 \ S \ H}{C} \ cm^3 \ (in^3)$$

where

 $C = 89 \times \text{stowage rate (m}^3/\text{tonne)}$

or in British units:-

 $C = 56.5 \times \text{stowage rate (ft}^3/\text{ton)}$

"Stowage rate" is the cubic capacity of holds, excluding hatchways, divided by the cargo deadweight or, in specific cases, is the cubic capacity of a particular hold divided by the weight of cargo stowed therein.

Longitudinal Side Framing

611 The section modulus of side longitudinals is not to be less than:—

$$\frac{1}{y} = \frac{\text{s S}^2}{120} \left(h_1 + \frac{2,5d - D}{6} \right) \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{\text{s S}^2}{2730} \, \left(h_1 + \frac{2 \cdot 5 d - D}{6} \right) \, \text{in}^3 \, \right)$$

where h_1 = distance of longitudinal below deck at side, in metres (feet), and d is not to be taken as less than 0,4D. The section modulus need not exceed that determined from 606 for bottom longitudinals, but where the span of the side longitudinals exceeds 2,5 m (8·2 ft) this modulus should be determined from 606 with S = 2,5 m (8·2 ft) and increased by the factor:—

$$\left(\frac{\text{Span of side longitudinals in metres (feet)}}{2.5 \text{ m (8.2 ft)}}\right)^2$$

The section modulus of side longitudinals in topside wing tanks is to be that determined as above, but is not to be less than required for the sloping bulkhead (see 615).

612 Webs supporting side longitudinals are, in general, not to be spaced more than 3,7 m (12·1 ft) apart when the length L does not exceed 185 m (605 ft) and $\frac{L}{50}$ for lengths greater than this, and their section modulus is not to be less than:—

$$\frac{I}{V} = 10 \text{ s}_1 \text{ h}_2 \text{ S}_1^2 \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{s_1 h_2 s_1^2}{190} in^3 \right)$$

where S₁ = spacing of webs, in metres (feet),

h₂ = distance, in metres (feet), from mid-point of span to upper deck at side amidships,

 $S_1 = \text{span of web, in metres (feet)}$

Where topside tanks are fitted or an Ore or Heavy Cargo notation is to be assigned, the strength of these webs may require to be increased. In general, the standard of strength is not to be less than that required by D 715, D 716 and D 717.

For arrangements in machinery spaces at aft end, see D 55.

For arrangements in fore and aft peaks, see D 54 and D 55.

Bilge Longitudinals

613 The scantlings of bilge longitudinals are to be graduated between those required for the bottom longitudinals and lowest side longitudinal.

Hopper Side Tanks

614 If longitudinals are fitted to the sloping tank top forming a hopper side tank, their section modulus is not to be less than required by 608, 609 or 610, as appropriate. H may, in this case, be measured vertically from the centre of the sloping portion to the intersection with the sloping plating of the topside tank, or to the deck at side if no topside tank is fitted.

Topside Wing Tank

615 Longitudinals on the sloping bulkhead of topside tanks are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{H_1 \, s \, S^2}{100} \, cm^3$$
 $\left(\frac{I}{y} = \frac{H_1 \, s \, S^2}{2275} \, in^3\right)$

where H₁ is the greater of the following heads, in metres (feet):—

- (a) measured from the outboard longitudinal to the gunwale or outboard corner of the tank,
- (b) two-thirds of the distance, measured parallel to the plating, from the outboard longitudinal to the inboard corner of the tank.

Where a plate diaphragm is fitted the longitudinals inboard of this may be determined using H equal to the perpendicular distance between the sloping bulkhead and the gunwale or outboard corner of the tank.

General

616 The thickness of flat bar longitudinals continuous at bulkheads is not to be less than one eighteenth of the depth. Where not continuous, the thickness should not be less than one-fifteenth of the depth.

Longitudinals of the flat bar type are not to be scalloped, but isolated drain or air holes may be provided.

Flat bar longitudinals (if cut from plate) and through brackets to longitudinals, on deck, bottom and side shell for 0,1D from deck and bottom, are to be of the following Grades of steel for 0,4L amidships:—

Grade B where thickness exceeds 20,5 mm (0.8 in) but does not exceed 25,5 mm (1.0 in),

Grade D where thickness exceeds 25,5 mm (1.0 in).

Built longitudinals are to comply with the requirements of D 4008 and D 4404. For higher tensile steel, see D 6519.

TABLE D 6.1

LINE	LOCATION OF WEATHER DECK LONGITUDINAL	K ₁	K ₂	h (metres (feet))
1	0,4L amidships outside line of openings (See Note 2)	5,70 (2·7)	0.72 (0·96)	1,2+2,04E (4+6.7E) but not less than 1,2 (4.0) nor greater than 1,5 (5.0) (See Note 3)
2	At 0,12 from F.P. outside line of openings	4,85 (2·3)	0,62 (0·83)	
3	At and abaft 0,1 L from A.P.	4,00 (1·9)	0,50 (0·67)	
4	Abaft 0,12∟ from F.P. within line of openings	4,00 (1.9)	0,50 (0·67)	
5	Between 0,12L and 0,075L from F.P. outside and inside line of openings	5,70 (2·7)	0,72 (0·96)	1,5 (5.0)
6	Forward of 0,075 L from F.P. outside and inside line of openings	6,35 (3·0)	0,78 (1·04)	1,8 (6.0)
7	Bridge where forming an effective super- structure	6,75 (3·2)	0,72 (0.96)	0,9+2,04E (3+6·7E) but not less than 0,9 (3·0) nor greater than 1,2 (4·0)
8	Short bridge or poop (L ₁ for short bridge or poop need not be taken as greater than 153 m (502 ft))	4,65 (2·2)	0,50 (0·67)	

Notes. 1.
$$E = \frac{0.0914 + 0.003L}{D-d} - 0.15$$

 $\left(E = \frac{0.3 + 0.003L}{D-d} - 0.15 \text{ British}\right)$

- 2. The amidship scantlings of longitudinals as determined from Line 1 may be tapered to the values determined from Lines 2 and 3.
- 3. For decks above the uppermost continuous deck, h obtained from the formula for lines 1 to 4 can be successively reduced by 0,31 m (1.02 ft) for each deck to a minimum of 0,45 m (1.48 ft).

610 "Strengthened for Heavy or Ore Cargoes— Specified Holds may be Empty" notation.

The section modulus of rolled sections is not to be less than:—

$$\frac{I}{V} = \frac{S^2 \ S \ H}{C} \ cm^3 \ (in^3)$$

where

 $C = 89 \times \text{stowage rate (m}^3/\text{tonne)}$

or in British units:-

 $C = 56.5 \times \text{stowage rate (ft}^3/\text{ton)}$

"Stowage rate" is the cubic capacity of holds, excluding hatchways, divided by the cargo deadweight or, in specific cases, is the cubic capacity of a particular hold divided by the weight of cargo stowed therein.

Longitudinal Side Framing

611 The section modulus of side longitudinals is not to be less than:—

$$\frac{1}{y} = \frac{\text{s S}^2}{120} \left(\text{h}_1 + \frac{2,5\text{d} - \text{D}}{6} \right) \, \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{\text{s S}^2}{2730} \; \left(h_1 + \frac{2 \cdot 5 d - D}{6} \right) \; \mathrm{in}^3 \, \right)$$

where h_1 = distance of longitudinal below deck at side, in metres (feet), and d is not to be taken as less than 0,4D. The section modulus need not exceed that determined from 606 for bottom longitudinals, but where the span of the side longitudinals exceeds 2,5 m (8·2 ft) this modulus should be determined from 606 with S = 2,5 m (8·2 ft) and increased by the factor:—

$$\left(\frac{\text{Span of side longitudinals in metres (feet)}}{2,5 \text{ m (8.2 ft)}}\right)^2$$

The section modulus of side longitudinals in topside wing tanks is to be that determined as above, but is not to be less than required for the sloping bulkhead (see 615).

612 Webs supporting side longitudinals are, in general, not to be spaced more than 3,7 m (12·1 ft) apart when the length \bot does not exceed 185 m (605 ft) and $\frac{\bot}{50}$ for lengths greater than this, and their section modulus is not to be less than:—

$$\frac{I}{V} = 10 \text{ S}_1 \text{ h}_2 \text{ S}_1^2 \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{s_1 h_2 S_1^2}{190} in^3\right)$$

where S₁ = spacing of webs, in metres (feet),

h₂ = distance, in metres (feet), from mid-point of span to upper deck at side amidships,

 $S_1 = \text{span of web, in metres (feet)}$.

Where topside tanks are fitted or an Ore or Heavy Cargo notation is to be assigned, the strength of these webs may require to be increased. In general, the standard of strength is not to be less than that required by D 715, D 716 and D 717.

For arrangements in machinery spaces at aft end, see D 55.

For arrangements in fore and aft peaks, see D 54 and D 55.

Bilge Longitudinals

613 The scantlings of bilge longitudinals are to be graduated between those required for the bottom longitudinals and lowest side longitudinal.

Hopper Side Tanks

614 If longitudinals are fitted to the sloping tank top forming a hopper side tank, their section modulus is not to be less than required by 608, 609 or 610, as appropriate. H may, in this case, be measured vertically from the centre of the sloping portion to the intersection with the sloping plating of the topside tank, or to the deck at side if no topside tank is fitted.

Topside Wing Tank

615 Longitudinals on the sloping bulkhead of topside tanks are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{H_1 \, s \, S^2}{100} \, cm^3$$
 $\left(\frac{I}{y} = \frac{H_1 \, s \, S^2}{2275} \, in^3\right)$

where H₁ is the greater of the following heads, in metres (feet):—

- (a) measured from the outboard longitudinal to the gunwale or outboard corner of the tank,
- (b) two-thirds of the distance, measured parallel to the plating, from the outboard longitudinal to the inboard corner of the tank.

Where a plate diaphragm is fitted the longitudinals inboard of this may be determined using H equal to the perpendicular distance between the sloping bulkhead and the gunwale or outboard corner of the tank.

General

616 The thickness of flat bar longitudinals continuous at bulkheads is not to be less than one eighteenth of the depth. Where not continuous, the thickness should not be less than one-fifteenth of the depth.

Longitudinals of the flat bar type are not to be scalloped, but isolated drain or air holes may be provided.

Flat bar longitudinals (if cut from plate) and through brackets to longitudinals, on deck, bottom and side shell for 0,1D from deck and bottom, are to be of the following Grades of steel for 0,4L amidships:—

> Grade B where thickness exceeds 20,5 mm (0.8 in) but does not exceed 25,5 mm (1.0 in),

Grade D where thickness exceeds 25,5 mm (1.0 in).

Built longitudinals are to comply with the requirements of D 4008 and D 4404. For higher tensile steel, see D 6519.

TABLE D 6.1

LINE	LOCATION OF WEATHER DECK LONGITUDINAL	K ₁	K ₂	h (metres (feet))
1	0,4L amidships outside line of openings (See Note 2)	5,70 (2·7)	0.72 (0·96)	1,2+2,04E (4+6.7E) but not less than 1,2 (4.0) nor greater than 1,5 (5.0) (See Note 3)
2	At 0,12 L from F.P. outside line of openings	4,85 (2·3)	0,62 (0·83)	
3	At and abaft 0,1L from A.P.	4,00 (1·9)	0,50 (0·67)	
4	Abaft 0,12∟ from F.P. within line of openings	4,00 (1·9)	0,50 (0·67)	
5	Between 0,12L and 0,075L from F.P. outside and inside line of openings	5,70 (2·7)	0,72 (0·96)	1,5 (5.0)
6	Forward of 0,075 L from F.P. outside and inside line of openings	6,35 (3.0)	0,78 (1·04)	1,8 (6.0)
7	Bridge where forming an effective super- structure	6,75 (3·2)	0,72 (0·96)	0,9+2,04E (3+6·7E) but not less than 0,9 (3·0) nor greater than 1,2 (4·0)
8	Short bridge or poop (L ₁ for short bridge or poop need not be taken as greater than 153 m (502 ft))	4,65 (2·2)	0,50 (0·67)	

Notes. 1.
$$E = \frac{0.0914 + 0.003L}{D-d} - 0.15$$

 $\left(E = \frac{0.3 + 0.003L}{D-d} - 0.15 \text{ British}\right)$

- 2. The amidship scantlings of longitudinals as determined from Line 1 may be tapered to the values determined from Lines 2 and 3.
- 3. For decks above the uppermost continuous deck, h obtained from the formula for lines 1 to 4 can be successively reduced by 0,31 m (1.02 ft) for each deck to a minimum of 0,45 m (1.48 ft).

610 "Strengthened for Heavy or Ore Cargoes— Specified Holds may be Empty" notation.

The section modulus of rolled sections is not to be less than:—

$$\frac{I}{V} = \frac{S^2 \ s \ H}{C} \ cm^3 \ (in^3)$$

where

 $C = 89 \times \text{stowage rate (m}^3/\text{tonne)}$

or in British units:-

 $C = 56.5 \times \text{stowage rate (ft}^3/\text{ton)}$

"Stowage rate" is the cubic capacity of holds, excluding hatchways, divided by the cargo deadweight or, in specific cases, is the cubic capacity of a particular hold divided by the weight of cargo stowed therein.

Longitudinal Side Framing

611 The section modulus of side longitudinals is not to be less than:—

$$\frac{1}{y} = \frac{\text{s S}^2}{120} \left(h_1 + \frac{2,5d-D}{6} \right) \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{\text{s S}^2}{2730} \, \left(\text{h}_1 + \frac{2 \cdot 5 \text{d} - \text{D}}{6} \right) \, \text{in}^3 \, \right)$$

where h_1 = distance of longitudinal below deck at side, in metres (feet), and d is not to be taken as less than 0,4D. The section modulus need not exceed that determined from 606 for bottom longitudinals, but where the span of the side longitudinals exceeds 2,5 m (8·2 ft) this modulus should be determined from 606 with S = 2,5 m (8·2 ft) and increased by the factor:—

$$\left(\frac{\text{Span of side longitudinals in metres (feet)}}{2,5 \text{ m (8.2 ft)}}\right)^2$$

The section modulus of side longitudinals in topside wing tanks is to be that determined as above, but is not to be less than required for the sloping bulkhead (see 615).

612 Webs supporting side longitudinals are, in general, not to be spaced more than 3,7 m (12·1 ft) apart when the length \bot does not exceed 185 m (605 ft) and $\frac{\bot}{50}$ for lengths greater than this, and their section modulus is not to be less than:—

$$\frac{I}{V} = 10 \text{ s}_1 \text{ h}_2 \text{ S}_1^2 \text{ cm}^3$$

$$\binom{I}{y} = \frac{s_1 h_2 S_1^2}{190} in^3$$

where S₁ = spacing of webs, in metres (feet),

h₂ = distance, in metres (feet), from mid-point of span to upper deck at side amidships,

 $S_1 = \text{span of web, in metres (feet)}$

Where topside tanks are fitted or an Ore or Heavy Cargo notation is to be assigned, the strength of these webs may require to be increased. In general, the standard of strength is not to be less than that required by D 715, D 716 and D 717.

For arrangements in machinery spaces at aft end, see D 55.

For arrangements in fore and aft peaks, see D 54 and D 55.

Bilge Longitudinals

613 The scantlings of bilge longitudinals are to be graduated between those required for the bottom longitudinals and lowest side longitudinal.

Hopper Side Tanks

614 If longitudinals are fitted to the sloping tank top forming a hopper side tank, their section modulus is not to be less than required by 608, 609 or 610, as appropriate. H may, in this case, be measured vertically from the centre of the sloping portion to the intersection with the sloping plating of the topside tank, or to the deck at side if no topside tank is fitted.

Topside Wing Tank

615 Longitudinals on the sloping bulkhead of topside tanks are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{H_1 \otimes S^2}{100} \text{ cm}^3$$
 $\left(\frac{I}{y} = \frac{H_1 \otimes S^2}{2275} \text{ in}^3\right)$

where H₁ is the greater of the following heads, in metres (feet):—

- (a) measured from the outboard longitudinal to the gunwale or outboard corner of the tank,
- (b) two-thirds of the distance, measured parallel to the plating, from the outboard longitudinal to the inboard corner of the tank.

Where a plate diaphragm is fitted the longitudinals inboard of this may be determined using H equal to the perpendicular distance between the sloping bulkhead and the gunwale or outboard corner of the tank.

General

616 The thickness of flat bar longitudinals continuous at bulkheads is not to be less than one eighteenth of the depth. Where not continuous, the thickness should not be less than one-fifteenth of the depth.

Longitudinals of the flat bar type are not to be scalloped, but isolated drain or air holes may be provided.

Flat bar longitudinals (if cut from plate) and through brackets to longitudinals, on deck, bottom and side shell for 0,1D from deck and bottom, are to be of the following Grades of steel for 0,4L amidships:—

Grade B where thickness exceeds 20,5 mm (0.8 in) but does not exceed 25,5 mm (1.0 in),

Grade D where thickness exceeds 25,5 mm (1.0 in).

Built longitudinals are to comply with the requirements of D 4008 and D 4404. For higher tensile steel, see D 6519.

TABLE D 6.1

LINE	LOCATION OF WEATHER DECK LONGITUDINAL	K ₁	K ₂	h (metres (feet))
1	0,4L amidships outside line of openings (See Note 2)	5,70 (2·7)	0.72 (0·96)	1,2+2,04E (4+6.7E) but not less than 1,2 (4.0) nor greater than 1,5 (5.0) (See Note 3)
2	At 0,12 L from F.P. outside line of openings	4,85 (2·3)	0,62 (0·83)	
3	At and abaft 0,1 L from A.P.	4,00 (1·9)	0,50 (0·67)	
4	Abaft 0,12L from F.P. within line of openings	4,00 (1·9)	0,50 (0·67)	
5	Between 0,12L and 0,075L from F.P. outside and inside line of openings	5,70 (2·7)	0,72 (0.96)	1,5 (5.0)
6	Forward of 0,075 L from F.P. outside and inside line of openings	.6,35 (3·0)	0,78 (1·04)	1,8 (6.0)
7	Bridge where forming an effective super- structure	6,75 (3·2)	0,72 (0·96)	0,9+2,04E (3+6·7E) but not less than 0,9 (3·0) nor greater than 1,2 (4·0)
8	Short bridge or poop (L ₁ for short bridge or poop need not be taken as greater than 153 m (502 ft))	4,65 (2·2)	0,50 (0·67)	

Notes. 1.
$$E = \frac{0.0914 + 0.003L}{D - d} - 0.15$$

$$\left(E = \frac{0.3 + 0.003L}{D - d} - 0.15 \text{ British}\right)$$

- 2. The amidship scantlings of longitudinals as determined from Line 1 may be tapered to the values determined from Lines 2 and 3.
- 3. For decks above the uppermost continuous deck, h obtained from the formula for lines 1 to 4 can be successively reduced by 0,31 m (1.02 ft) for each deck to a minimum of 0,45 m (1.48 ft).

610 "Strengthened for Heavy or Ore Cargoes— Specified Holds may be Empty" notation.

The section modulus of rolled sections is not to be less than:—

$$\frac{I}{y} = \frac{S^2 \ S \ H}{C} \ cm^3 \ (in^3)$$

where

 $C = 89 \times \text{stowage rate (m}^3/\text{tonne)}$

or in British units:-

 $C = 56.5 \times \text{stowage rate (ft}^3/\text{ton)}$

"Stowage rate" is the cubic capacity of holds, excluding hatchways, divided by the cargo deadweight or, in specific cases, is the cubic capacity of a particular hold divided by the weight of cargo stowed therein.

Longitudinal Side Framing

611 The section modulus of side longitudinals is not to be less than:—

$$\frac{1}{y} = \frac{\text{s S}^2}{120} \left(h_1 + \frac{2,5d - D}{6} \right) \text{ cm}^3$$

$$\left(\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{s}~\mathrm{S}^2}{2730}~\left(\mathrm{h}_1 + \frac{2 \cdot 5\mathrm{d} - \mathrm{D}}{6}\right)~\mathrm{in}^3\right)$$

where h_1 = distance of longitudinal below deck at side, in metres (feet), and d is not to be taken as less than 0,4D. The section modulus need not exceed that determined from 606 for bottom longitudinals, but where the span of the side longitudinals exceeds 2,5 m (8·2 ft) this modulus should be determined from 606 with S = 2,5 m (8·2 ft) and increased by the factor:—

$$\left(\frac{\text{Span of side longitudinals in metres (feet)}}{2,5 \text{ m (8.2 ft)}}\right)^2$$

The section modulus of side longitudinals in topside wing tanks is to be that determined as above, but is not to be less than required for the sloping bulkhead (see 615).

612 Webs supporting side longitudinals are, in general, not to be spaced more than 3,7 m (12·1 ft) apart when the length L does not exceed 185 m (605 ft) and $\frac{L}{50}$ for lengths greater than this, and their section modulus is not to be less than:—

$$\frac{I}{y} = 10 \text{ s}_1 \text{ h}_2 \text{ S}_1^2 \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{s_1 \; h_2 \; S_1^{\; 2}}{190} \; in^3 \; \right)$$

where S₁ = spacing of webs, in metres (feet),

h₂ = distance, in metres (feet), from mid-point of span to upper deck at side amidships,

S₁ = span of web, in metres (feet)

Where topside tanks are fitted or an Ore or Heavy Cargo notation is to be assigned, the strength of these webs may require to be increased. In general, the standard of strength is not to be less than that required by D 715, D 716 and D 717.

For arrangements in machinery spaces at aft end, see D 55.

For arrangements in fore and aft peaks, see D 54 and D 55.

Bilge Longitudinals

613 The scantlings of bilge longitudinals are to be graduated between those required for the bottom longitudinals and lowest side longitudinal.

Hopper Side Tanks

614 If longitudinals are fitted to the sloping tank top forming a hopper side tank, their section modulus is not to be less than required by 608, 609 or 610, as appropriate. H may, in this case, be measured vertically from the centre of the sloping portion to the intersection with the sloping plating of the topside tank, or to the deck at side if no topside tank is fitted.

Topside Wing Tank

615 Longitudinals on the sloping bulkhead of topside tanks are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{H_1 \, s \, S^2}{100} \, cm^3$$
 $\left(\frac{I}{y} = \frac{H_1 \, s \, S^2}{2275} \, in^3\right)$

where H_1 is the greater of the following heads, in metres (feet):—

- (a) measured from the outboard longitudinal to the gunwale or outboard corner of the tank,
- (b) two-thirds of the distance, measured parallel to the plating, from the outboard longitudinal to the inboard corner of the tank.

Where a plate diaphragm is fitted the longitudinals inboard of this may be determined using H equal to the perpendicular distance between the sloping bulkhead and the gunwale or outboard corner of the tank.

General

616 The thickness of flat bar longitudinals continuous at bulkheads is not to be less than one-eighteenth of the depth. Where not continuous, the thickness should not be less than one-fifteenth of the depth.

Longitudinals of the flat bar type are not to be scalloped, but isolated drain or air holes may be provided.

Flat bar longitudinals (if cut from plate) and through brackets to longitudinals, on deck, bottom and side shell for 0,1D from deck and bottom, are to be of the following Grades of steel for 0,4L amidships:—

> Grade B where thickness exceeds 20,5 mm (0.8 in) but does not exceed 25,5 mm (1.0 in),

Grade D where thickness exceeds 25,5 mm (1.0 in).

Built longitudinals are to comply with the requirements of D 4008 and D 4404. For higher tensile steel, see D 6519.

617 Where the L exceeds 215 m (705 ft) the bottom and deck longitudinals should be continuous through the transverse bulkheads, but alternative arrangements will be considered.

618 End connections of longitudinals to bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of longitudinal strength.

Section 7

TRANSVERSE SIDE FRAMING

Symbols

701 L = length of ship, in metres (feet).

D = moulded depth, in metres (feet).

 $D_1 = D$ but need not be taken as greater than 1.6d.

D₂ = D but need not be taken as greater than 1,6d or 16 m (52·5 ft) whichever is the lesser.

d = moulded draught, in metres (feet).

S = frame spacing, in mm (in).

H = (a) Main frames—vertical framing depth, in metres (feet), measured at side as indicated in Figs. D 7.1 and D 7.2.

(b) 'Tween deck frames—vertical 'tween deck height, in metres (feet), measured at side. In way of sheer, H is to-be measured, in general, at the middle of the length of each compartment. Where sheer is excessive, H will be specially considered.

Values of H in (a) and (b) are not to be less than 2.5 m (8.2 ft).

 $K = 1 - \frac{X}{5Q}$ but not less than 0,35.

X = distance, in metres (feet), measured as shown in Fig. D 7.2.

q = minimum height of double bottom, in metres (feet), as determined from D 904.

f = factor, obtained from Fig. D 7.3.

General

702 All scantlings for main frames are based on Rule welded end connections. If brackets differing from Rule size are fitted, the modulus of the frame is to be corrected—see 731.

703 The minimum inertia for all frames is given in 725.

Frame Spacing

704 The frame spacing between 0,2L from forward and the after peak bulkhead is not, in general, to exceed 1000 mm (39·4 in).

705 The frame spacing between 0,2L from forward and the fore peak bulkhead is not, in general, to exceed 700 mm (27.5 in) where D_1 is greater than 8,9 m (29 ft) and $\frac{1000D_1}{24} + 330$ mm $\left(\frac{\tilde{D}_1}{2} + 13 \text{ in}\right)$ where D_1 is less than 8,9 m (29 ft).

706 The frame spacing in peaks and cruiser sterns is not, in general, to exceed 610 mm (24 in).

Main and 'Tween Deck Frames

707 The section modulus of main and 'tween deck frames is not to be less than:—

between 0,2L aft of the forward perpendicular and the after peak bulkhead,

$$\frac{I}{y} = \frac{\text{Pds}}{760} \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{\text{Pds}}{30} \text{ in}^3\right) \tag{1}$$

between 0,2L aft of the forward perpendicular and the line of the fore peak bulkhead,

$$\frac{I}{y} = \frac{\text{Pdsf}}{700} \text{ cm}^3 \quad \left(\frac{I}{y} = \frac{\text{Pdsf}}{27 \cdot 5} \text{ in}^3\right) \quad (2)$$

'tween deck frames aft of the line of the after peak bulkhead and forward of the line of the fore peak bulkhead,

$$\frac{I}{y} = \frac{\text{Pdsf}}{610} \text{ cm}^3 \quad \left(\frac{I}{y} = \frac{\text{Pdsf}}{24} \text{ in}^3\right) \quad (3)$$

In (1), (2) and (3) above, P depends on where the lower end of the frame is connected as follows:—

to a double bottom of Rule height (main frame),

$$P = 1,35H^2 + 0,11D_1^2 + 11 \tag{4}$$

$$\left(P = \frac{H^2}{428} + \frac{D_1^2}{5260} + 0.205 \text{ British}\right)$$

to a hopper side tank or to a deep double bottom (main frame),

$$P = (1,35H^2 + 0,11KD_1^2 + 11)\left(1 - \frac{X}{1.4D}\right)$$
 (5)

$$\left(\mathsf{P} = \left(\frac{\mathsf{H^2}}{428} + \frac{\mathsf{KD_1}^2}{5260} + 0.205\right) \left(1 - \frac{\mathsf{X}}{1.4\mathsf{D}}\right) \; \mathrm{British}\right)$$

Where, due to the shape of the ship towards the ends, the rigidity of the hopper side tank is reduced, the modulus of the main frame may require to be increased.

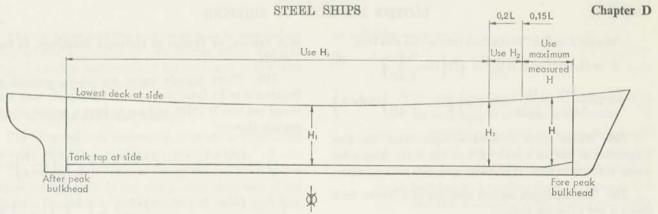


Fig. D 7.1—measurement of H for main frames allowing for sheer.

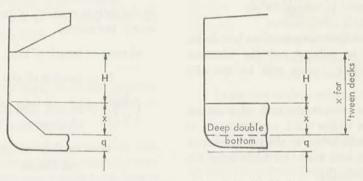


Fig. D 7.2—measurement of H, x and q where a hopper side tank or deep double bottom is fitted. (For 'tween decks x is to be measured excluding sheer).

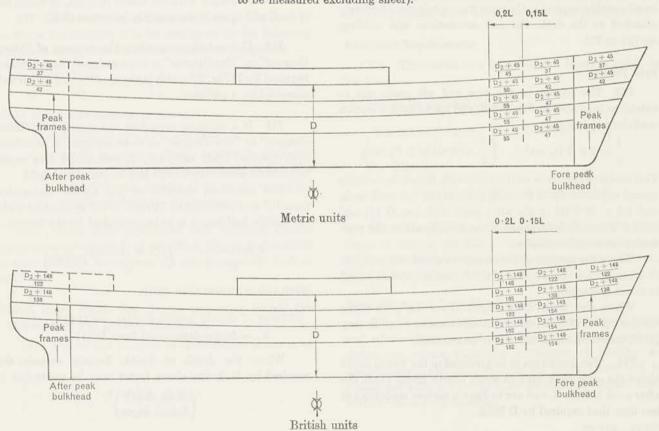


Fig. D 7.3—showing distribution of factor f.

to a deck or flat ('tween deck frame-see also 709),

$$P = (1,35H^{2} + 0,11D_{1}^{2} + 11)\left(1 - \frac{X}{1,4D}\right)$$

$$\left(P = \left(\frac{H^{2}}{428} + \frac{D_{1}^{2}}{5260} + 0.205\right)\left(1 - \frac{X}{1.4D}\right) \text{ British}\right)$$

708 Where spans forward of 0,2L from the fore perpendicular are in excess of 9 m (29.5 ft), intercostal stringers are to be fitted in line with alternate peak stringers.

709 The minimum section modulus of a 'tween deck frame is not to be less than:—

$$\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathsf{D_{1}S}}{110} \ \mathrm{cm^{3}} \qquad \left(\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathsf{D_{1}S}}{230} \ \mathrm{in^{3}} \right)^{-1}$$

710 At positions where there are more than four decks, the modulus in 707 may be reduced and the minimum modulus of the 'tween deck frames will be specially considered.

711 The four frames nearest the end of a superstructure which terminates within 0,25L amidships are to extend from the 'tween decks below to the superstructure deck. Equivalent arrangements are to be made when the ship's side is framed longitudinally.

712 All 'tween deck and superstructure frames are to be efficiently scarphed to the main frames below or effectively attached to the deck. For end connections and welding, see 727 to 735.

Peak Frames

713 The frames in the fore and aft peaks are to extend as indicated in Fig. D 7.3, and are to have a section modulus not less than:—

$$\frac{I}{y} = 2.8 \text{ d D}_2 \text{ cm}^3 \qquad \left(\frac{I}{y} = 0.0159 \text{ d D}_2 \text{ in}^3\right)$$

This modulus applies in conjunction with Rule side stringers spaced vertically 2,0 m (6.56 ft) apart in the fore peak tank, and 2,5 m (8.2 ft) in the after peak tank (see D 11) and with a 'tween deck height of 2,6 m (8.5 ft) above the peak tanks, measured vertically.

Where the spacing of the stringers exceeds 2,0 or 2,5 m (6.56 or 8.2 ft), the modulus of the frames is to be increased in direct proportion.

Where the 'tween deck height above the peak tanks exceeds 2,6 m (8.5 ft), or where curvature or slope is very great, intermediate stringers may be required.

714 Web frames are to be arranged in the 'tween decks above the after peak tank at every fourth frame abaft the after peak bulkhead, and are to have a section modulus not less than that required by D 5512.

Web Frames, or Frames of Increased Scantlings, in Cargo Holds

715 Where topside tanks are fitted, vertical web frames are to be fitted in line with the topside tank transverses (see also D 1918), and are to have a section modulus not less than:—

$$\frac{\mathrm{I}}{\mathrm{y}} = \frac{\left(\mathrm{2D} - \mathrm{H} - \mathrm{q} - \mathrm{x}\right) \, l \, \mathrm{Hs_1}}{7.0} + \left(\frac{\mathrm{I}}{\mathrm{y}}\right)_f \left(1 - \frac{\mathrm{n}}{4}\right) \mathrm{cm}^3$$

$$\left(\frac{I}{y} = \frac{(2D - H - q - x) l H s_1}{13300} + \left(\frac{I}{y}\right)_f \left(1 - \frac{n}{4}\right) in^3\right)$$

or the section modulus of the adjacent main frame, whichever is the greater,

where l = length of hold, in metres (feet),

S₁ = spacing of web frames, in metres (feet),

$$\left(\frac{1}{y}\right)_{f}$$
 = section modulus of main frame in cm³ (in³) obtained from 707,

n = number of frame spaces between adjacent web frames.

Alternatively, the scantlings of the main frames may be increased to comply with the above formula, in which case n=1, and $s_1=$ frame spacing, in metres (feet).

716 If a notation regarding the carriage of "Heavy Cargoes" or "Ore Cargoes" is to be assigned the modulus as required by 707 or, if topside tanks are fitted by 715, is to be increased by 4 per cent.

717 If a notation regarding the carriage of "Heavy Cargoes" or "Ore Cargoes" is to be assigned in association with specified holds being empty, web frames may require to be fitted within the middle half-length of each hold.

The combined modulus of the frames (determined from 707 and corrected by 715 and 716 if applicable) within the middle half-length is to be multiplied by the factor:—

$$\frac{4 \text{ w } (1-k_1)}{\text{d}} \qquad \left(\frac{144 \text{ w } (1-k_1)}{\text{d}} \text{ British}\right)$$

when this is greater than unity,

where W = double bottom loading, see D 941,

k₁ = factor determined from D 941.

Where the depth of double bottom exceeds that required by D 9, the above factor may be multiplied by

The combined modulus so derived is to be attained by fitting a suitable number of web frames which must be within the middle half-length of the hold, and in line with transverses in the top side tanks (if fitted).

Frames in Engine and Boiler Room

718 Vertical web frames are, in general, to be fitted in the engine room.

The combined section modulus of web and main frames is to be not less than 50 per cent greater than that of the Rule main frames up to the lowest deck above the waterline.

The web frames in midship machinery spaces may be omitted provided the overall strength is maintained.

Where machinery spaces are at the after end, the arrangements are to comply with D 55.

Side Framing in way of Tanks

719 Paragraphs 720 to 722 apply to oil fuel bunkers, settling tanks, and deep tanks used for water ballast or cargo oil.

720 The section modulus derived in accordance with 707 is to be increased by 15 per cent (except where the tank is situated forward of 0,15L) but may require to be further increased to comply with 721.

721 Where the top of the tank is above the head of the frame the modulus is to be that given by the following formula or as required by 720, whichever is the greater:—

$$\frac{I}{y} = \frac{s H^2 h}{150} cm^3$$
 $\left(\frac{I}{y} = \frac{s H^2 h}{3430} in^3\right)$

where S = frame spacing, in mm (in),

H as defined in 701. (See also 722),

h = head, in metres (feet), measured from the middle of H to the deck at side or half the head from the middle of H to the top of the overflow, whichever is the greater.

722 Where fully supporting side stringers, having scantlings according to D 19 are fitted, H may be measured between stringers, or between the stringer and the deck or tank top.

Frames under Hatch End Beams supporting Hatch Side Girders or in way of Deck Transverses

723 The section modulus of these frames is not to be less than:—

$$\frac{I}{y} = 2.5 \, \left(\frac{\it l^2}{\it 5} \, + H^2 \right) h_{\rm t} \, S_{\rm t} \, \, {\rm cm^3}$$

or in British units:-

$$\frac{\mathrm{I}}{\mathrm{y}} = \left(\frac{l^2}{5} + \mathrm{H}^2\right) \quad \frac{\mathrm{h_t \ S_t}}{760} \ \mathrm{in^3}$$

where l = distance, in metres (feet), from side shell to inboard support of beam or transverse,

H = vertical framing depth or 'tween deck height of frame concerned, as defined in 701 but need not be taken greater than 3,5 m (11.5 ft),

h_t = load height, in metres (feet), as given in D 6 and D 8. (See also D 1304, D 1319 and D 25),

St is defined as follows:-

(a) at hatch end beams S_t = length of hatch, in metres (feet), divided by 4, but not less than that given in (b),

(b) at transverses $S_t = \text{actual spacing of transverses}$, in metres (feet).

In no case is the modulus to be less than that required for the normal side frame.

724 Where the modulus required for frames under deck transverses exceeds that obtained from 707 and 720 to 722, the intermediate frames may be reduced provided the combined modulus is maintained and the reduction in any intermediate frame is not greater than 35 per cent. The reduced modulus is not to be less than that given in 709.

Additional Requirements

725 The inertia of a frame or web frame is not to be less than:—

(a) In the forward 0,15L

$$I=3.5~\text{H}~\frac{I}{y}~\text{cm}^4~\left(I=0{\cdot}42^{^g}\text{H}\frac{I}{y}~\text{in}^4\right)$$

(b) Elsewhere

$$I = 3.2 \text{ H} \frac{I}{V} \text{ cm}^4 \left(I = 0.38 \text{ H} \frac{I}{V} \text{ in}^4 \right)$$

726 Where holes are drilled or punched in the inboard flange of frames, the size of the frame may require to be increased in order to maintain the required section modulus in way of the holes.

Beam Knees and Tank Side Brackets

727 In ships having more than three tiers of beams and where large areas of deck are arranged for accommodation, or where particular conditions of loading are contemplated, the requirements for beam knees will be considered with a view to their omission in certain areas without increase in modulus.

728 Where frames are connected to deck transverses and hatch end beams, the scantlings of the brackets are to be determined from D 1311.

729 Where web frames (see 715 to 717) have continuous face flats, the end connections are to have strength equivalent to the requirements of 730 to 735.

730 The sketches in Fig. D 7.4 are intended to be diagrammatic only, to show the method of measuring the arm lengths of beam knees and tank side brackets.

Frame Correction and Rule Arms of Knees and Brackets

731 When the effective arm of the knee or bracket l_a (see Fig. D 7.4) differs from the Rule arm l, the frame modulus is to be multiplied by the factor below:—

when
$$l_a < l$$
 factor = 1,2 - 0,2 $\frac{l_a}{l}$
when $l_a > l$ factor = 1,1 - 0,1 $\frac{l_a}{l}$

where:-

(a) For a beam knee:—the Rule length of arm l, measured as indicated for a and b in Fig. D 7.4, is

$$21\sqrt{\frac{I}{y}} - 51 \text{ mm} \quad \left(3.35\sqrt{\frac{I}{y}} - 2 \text{ in}\right)$$

with a minimum of 165 mm (6.5 in), where $\frac{I}{y}$ is the Rule section modulus in cm³ (in³) and is to be taken as follows:—

At decks where the hold frames terminate, and at the lower deck in the panting region $\frac{I}{y}$ is to be that of the frame or beam, whichever is greater. At all other decks the dimensions are to be based on the modulus of the beam.

If the frame is continuous, the $\frac{1}{y}$ to be used in the above formula is that of the beam.

Where the modulus of the frame or beam is less than 590 cm³ (36 in³) and the knee has a flange of the size required by 734, l may be reduced by 15 per cent.

(b) For a tank side bracket:—where tank side brackets are connected to a double bottom or hopper side tank, \(\lambda \) is to be taken not less than 20 per cent greater than that required for the beam knee, or 0,4 times the Rule height of double bottom, whichever is the greater.

Length of Overlap

732 The Rule length of overlap of knee or bracket on frame or beam, measured along the frame or beam, is not to be less than:—

$$11.3\sqrt{\frac{1}{y}}$$
 or $d_f mm \left(1.8\sqrt{\frac{1}{y}} \text{ or } d_f in\right)$

where $\frac{I}{y}$ is the Rule section modulus in cm³ (in³) and d_f is the depth in mm (in), of the lower frame for types 2 to 4 and 6 to 9, in Fig. D 7.4 and of the beam or frame, whichever is the greater, for type 1. For type 5, $\frac{I}{y}$ is the modulus of the beam or the frame, as applicable.

For upper frames of types 4 to 6 the connection need only be that necessary to provide the required area of weld.

Welding

733 The weld area connecting the knee or bracket to beam or frame is not to be less than:—

$$2.4 \sqrt{\frac{I}{y}} - 19.5 \text{ cm}^2 \text{ where } \frac{I}{y} < 345 \text{ cm}^3$$

$$\left(1.5 \sqrt{\frac{I}{y}} - 3 \text{ in}^2 \text{ where } \frac{I}{y} < 21 \text{ in}^3 \right)$$

$$1.1 \sqrt{\frac{I}{y}} + 4 \text{ cm}^2 \text{ where } \frac{I}{y} \geqslant 345 \text{ cm}^3$$

$$\left(0.7 \sqrt{\frac{I}{y}} + 0.7 \text{ in}^2 \text{ where } \frac{I}{y} \geqslant 21 \text{ in}^3 \right)$$

where $\frac{1}{y}$ is the section modulus as defined in 732.

For increased connection of tank side brackets to frames in the panting region, see D 1108.

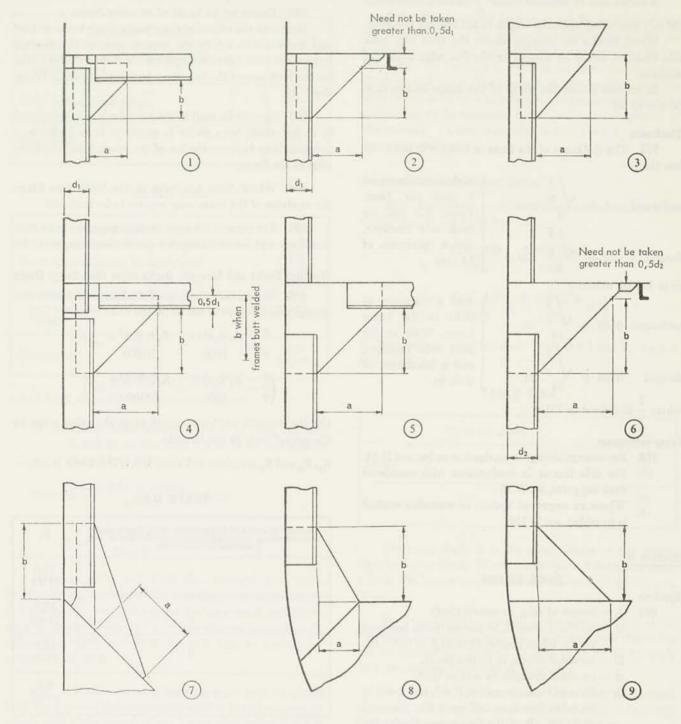
The weld area connecting the upper frames to the deck for types 5 and 6 in Fig. D 7.4, is based on the modulus of the upper frame only.

In the above formulæ, and where the bracket or knee is connected to the deck or the shell, the weld throat thickness (leg length) is not to be less than $0.28 \times$ the plate thickness with a minimum of 3.5 mm ($0.40 \times$ the plate thickness with a minimum of 0.18 in).

Flange

734 Where $\frac{I}{y}$ as defined in 731, is greater than 590 cm³ (36 in³) a flange of width not less than

$$2.1\sqrt{\frac{1}{y}}$$
 mm $\left(\frac{\sqrt{\frac{1}{y}}}{3}$ in $\right)$ is to be fitted.



Note. Effective arm l_a to be used in 731 is $\frac{a+b}{2}$ but is not to be taken greater than 1,2 times a or b, whichever is the lesser.

Fig. D 7.4

A flange may be required when $\frac{I}{y}$ is less than 590 cm³ (36 in³) depending upon the length of the bracket free edge.

Where frames are stopped above the tank top, tank side brackets are to be flanged or the free edge otherwise stiffened.

In no case should the width of the flange be less than 50 mm (2 in).

Thickness

735 The thickness of the knee or bracket is not to be less than:—

unflanged
$$4 + \frac{\sqrt{\frac{1}{y}}}{3} \text{ mm}$$
flanged $2 + \frac{\sqrt{\frac{1}{y}}}{3} \text{ mm}$

with a minimum of 7 mm for beam knees, 8,5 mm for tank side brackets, and a maximum of 14 mm.

or in British units:-

unflanged
$$0.16 + \frac{\sqrt{\frac{I}{y}}}{19}$$
 in flanged $0.08 + \frac{\sqrt{\frac{I}{y}}}{19}$ in where $\frac{I}{y}$ is defined in 731.

with a minimum of 0.28 in for beam knees, 0.34 in for tank side brackets, and a maximum of 0.55 in.

Cross-references

736 For strengthening for navigation in ice, see D 24.

For side frames in conjunction with cantilever deck supports, see D 15.

Where an approved system of corrosion control is provided, see D 110.

Section 8

DECK BEAMS

Symbols

1 L = length of ship, in metres (feet).

- B = moulded breadth, in metres (feet), but need not be taken greater than 21,5 m (70.5 ft).
- D = moulded depth, in metres (feet).
- d = moulded draught, in metres (feet).
- S = Span of beam, in metres (feet), but is not to be taken less than 1,83 m (6 ft). Forward of 0,075L aft of the fore perpendicular the span of forecastle and weather deck beams is not to exceed 3,7 m (12·1 ft). See also 803.
- s = beam spacing in mm (in).
- h = load height, in metres (feet). See 806, 809 and D 25.

General

802 Beams are to be fitted at every frame.

Beams at the crown of deep tanks, peak tanks and oil fuel tanks are to satisfy the requirements of this Section but are not to be less in strength standard than that required for the stiffeners of the boundary bulkheads to those tanks. See D 19.

- 803 Span to be used in the formulæ is to be measured in metres (feet) from girder to girder or from girder to a point midway between the toe of the bracket and the inner edge of the frame.
- 804 Where there are holes in the beam face flange the modulus of the beam may require to be increased.
- 805 For permissible deck loading appropriate to Rule scantlings and for scantlings for specific loadings, see D 25.

Weather Decks and Strength Decks other than Cargo Decks

806 The section modulus of weather deck beams and strength deck beams is not to be less than:—

$$\begin{split} \frac{\mathrm{I}}{\mathrm{y}} &= \frac{\mathrm{K_1 \, K_2 \, d \, D}}{1000} + \frac{\mathrm{K_3 \, h \, B \, S^2 \, s}}{10\,000} \, \, \mathrm{cm^3} \\ \left(\frac{\mathrm{I}}{\mathrm{y}} &= \frac{\mathrm{K_1 \, K_2 \, d \, D}}{1000} + \frac{\mathrm{K_3 \, h \, B \, S^2 \, s}}{100\,000} \, \, \mathrm{in^3} \right) \end{split}$$

but the modulus need not exceed twice the value given by the second term in the formula.

K₁, K₂ and K₃ are given in Tables D 8.1, D 8.2 and D 8.3:—

TABLE D 8.1

Number of decks at the position of the beam under consideration, including superstructure decks, but excluding forecastles	K ₁
1	20,0 (1·5)
2	13,3 (1·0)
3	10,5 (0·8)
4 or more	9,3 (0·7)

Notes. 1. The K₁ value for a forecastle deck may be taken as 13,3 (1.0).

A sloping topside tank may be counted as a deck.

TABLE D 8.2

LOCATION OF BEAM	K ₂
Forward of a point 0,12L aft of the fore perpendicular	80,0 (6·0)
Short bridges and poops	13,3 (1·0)
Elsewhere	53,0 (4·0)

TABLE D 8.3

LOCATION OF BEAM	K ₃
Beam span adjacent to ship's side	3,6 (0·48)
Forward of a point 0,075L abaft the fore perpendicular, on forecastles and weather decks	5,4 (0·72)
Elsewhere	3,3 (0·44)

Aft of 0,12L from the fore perpendicular:-

h = 1,2 + 2,04E metres (h = 4 + 6.7E ft), and is not to be less than 1,2 m (4 ft) nor greater than 1,5 m (5 ft).

where
$$E = \frac{0.0914 + 0.003L}{D - d} - 0.15$$

$$\left(\mathsf{E} = \frac{0.3 + 0.003 L}{\mathsf{D} - \mathsf{d}} - 0.15 \; \mathsf{British}\right)$$

Between 0,075L and 0,12L from forward, h is 1,5 m (5 ft). In the forward 0,075L, including forecastle decks, h is 1,8 m (6 ft). For decks above the uppermost continuous deck, h obtained from the above formulæ can be successively reduced by 0,310 m ($1 \cdot 02$ ft) for each deck, to a minimum of 0,450 m ($1 \cdot 48$ ft).

807 If the beams carry hanging cargo, such as chilled beef, the modulus determined from 806 is to be increased by 50 per cent if the height of the 'tween deck below is 2,6 m (8.5 ft) or less and 100 per cent if the height is 3,2 m (10.5 ft) (with intermediate heights in proportion), but the modulus need not exceed that derived from 810 for a 2,6 m (8.5 ft) 'tween deck height above. No increase is required if the modulus derived from 810 is less than that derived from 806.

Carriage of Timber on Weather Decks

808 Where timber load lines are to be assigned the modulus obtained from 806 is to be increased by 20 per cent for ships having a breadth up to and including 16,0 m (52.5 ft). No increase is required for breadths of 21.5 m (70.5 ft) and over. The increase at intermediate breadths is to be obtained by interpolation. In single deck ships the modulus is to be increased by 20 per cent irrespective of the breadth. (A ship with topside tanks is not considered as a single deck ship.)

Cargo and Accommodation Decks

809 The section modulus of cargo and accommodation deck beams is not to be less than:—

$$\frac{I}{y} = \frac{K_1 \; K_4 \; d \; D}{1000} + \frac{3,88 \; h \; S^2 \, s}{1000} \; \mathrm{cm}^3$$

$$\left(\frac{I}{y} = \frac{K_1 K_4 d D}{1000} + \frac{0.17 h S^2 s}{1000} in^3\right)$$

 K_1 is a constant obtained from Table D 8.1 and K_4 is given in Table D 8.4:—

TABLE D 8.4

TYPE OF DECK	K ₄
Cargo	40 (3)
Accommodation	53 (4)

For cargo decks h is the mean height of the 'tween deck in metres (feet). Where insulation is fitted underneath a deck, the 'tween deck height may be reduced by 150 mm (6 in).

For decks under accommodation spaces h is 1,2 m (4 ft). For decks above the uppermost continuous deck this value can be successively reduced by 0,31 m (1.02 ft) for each deck to a minimum of 0,45 m (1.48 ft).

Decks under ship store spaces other than refrigerated stores can, in general, he based on h equal to 2,0 m (6.56 ft). For engine room stores or flats h is 2,6 m (8.5 ft).

810 If cargo deck beams carry hanging cargo such as chilled beef and may be simultaneously loaded above with cargo, the modulus is to be determined from 809 with h increased by 0.76 m (2.5 ft) if the height of the 'tween

deck below is 2,6 m (8.5 ft) or less and 2,29 m (7.5 ft) if the height is 3,8 m (12.5 ft) (with intermediate heights in proportion). A similar addition is to be made, if appropriate, to accommodation deck beams.

Fork Lift Trucks

811 Where fork lift trucks are to be used, the section modulus of the beams is not to be less than:—

$$\frac{I}{\text{y}} = \frac{375 \, \text{K}_{\text{5}} \, \text{TS}}{1000} + \frac{1{,}25 \, \text{K}_{\text{6}} \, \text{h S}^2 \, \text{s}}{1000} \, \, \text{cm}^3 \, (\text{in}^3)$$

or that derived from 809 or 810 if appropriate, whichever is the greater,

where K5 and K6 are coefficients obtained from Table D 8.5,

T = total weight of truck and its load, in tonnes (tons).

TABLE D 8.5

DISTANCE BETWEEN LOAD BEARING WHEELS BEAM SPAN	K ₅	K ₆
0,1	15,4 (0·291)	1,89 (0·083)
0,2	14,6 (0·276)	1,845 (0·081)
0,3	13,35 (0·253)	1,730 (0·076)
0,4	11,8 (0·223)	1,55 (0·068)
0,5	10,1 (0·191)	1,30 (0·057)
0,6	8,46 (0·160)	0,98 (0·043)
0,7	7,78 (0·147)	0,66 (0·029)
0,8	6,77 (0·128)	0,343 (0·015)
0,9	4,28 (0·081)	0,091 (0.004)

Beam Knees and their Attachment

812 The scantlings of beam knees and their welded attachment are to be in accordance with D 727 to D 735.

813 In ships having more than three tiers of beams and where large areas of deck are arranged for accommodation, or where particular conditions of loading are contemplated, the requirements for beam knees will be considered.

814 The attachment of half beams to hatch side coamings and casings is given in Table D 32.1.

Cross-references

815 For strong hatch end beams and deck transverses, see D 13.

For strengthening in machinery spaces, see D 21. For cantilevers, see D 15.

Section 9

DOUBLE BOTTOMS

Symbols

901 L = length of ship, in metres (feet).

B = moulded breadth, in metres (feet).

d = moulded draught, in metres (feet).

S = spacing of frames or longitudinals, in mm (in).

D_{DB} = minimum depth of centre girder, in mm (in). See 904.

Application

902 This Section provides for longitudinal or transverse framing in the double bottom, but for ships exceeding 120 m (395 ft) in length, longitudinal framing is, in general, to be adopted. Longitudinal framing is to be adopted when a notation regarding the carriage of heavy or ore cargoes is to be assigned.

903 Where specified cargo holds may be empty in the loaded condition, see 940 to 948.

Centre Girder

904 The depth of the centre girder is not to be less than given by:—

$$D_{DB} = \frac{1000B}{36} + 205 \sqrt{d} \text{ mm}$$
 (1)
$$\left(D_{DB} = \frac{B}{3} + 4.5 \sqrt{d} \text{ in}\right)$$

The thickness is not to be less than:-

$$\begin{array}{l} t = 0.008D_{DB} + 4 \text{ mm} \\ (t = 0.008D_{DB} + 0.15 \text{ in}) \end{array} \text{ for 0,4L amidships}$$
 (2)

and
$$t = 0.008D_{DB} + 2 \text{ mm}$$

 $(t = 0.008D_{DB} + 0.08 \text{ in})$ for 0,1L at ends (3)
For duct keels, see 931.

Inner Bottom Plating

905 The thickness of the inner bottom plating throughout the holds is not to be less than:—

t = 0,001 36
$$\sqrt[4]{\text{Ld} (s + 660) \text{ mm}}$$
 for 0,4L amidships (1) (t = 0.000 75 $\sqrt[4]{\text{Ld} (s + 26) \text{ in}}$

t = 0,001 27
$$\sqrt[4]{\text{Ld}(s + 660) \text{ mm}}$$
 for 0,1L at ends (2) (t = 0.000 70 $\sqrt[4]{\text{Ld}(s + 26) \text{ in}}$

If a notation regarding the carriage of heavy cargoes or ore cargoes is to be assigned, the thickness derived from the the above is to be increased by 5 mm (0·20 in) but is not to be less than:—

$$t = \frac{s\sqrt{W}}{220}$$
 mm $\left(t = 0.015 \text{ s} \sqrt{W} \text{ in}\right)$ (3)

 $W = tank top loading in tonne/m^2 (ton/ft^2)$ and calculated as:—

 $\frac{\text{Weight of cargo in the hold}}{\text{Volume of the hold}} \times \frac{\text{Head from tank top to}}{\text{deck line at centre}}$

The thickness of the inner bottom plating as determined above is to be increased by 2 mm (0.08 in) under the hatchways if no ceiling is fitted and no increase has been made for heavy or ore cargoes.

For recommendations for thickness of plating when fork lift trucks are to be used, see D 418.

906 Where the double bottom tanks are common with wing ballast tanks or cofferdams, the thickness of the inner bottom plating is to be not less than required by D 1919 for the crown of a tank.

907 If cargo is to be regularly discharged by grabs from ships not having heavy cargoes or ore cargoes notation it is recommended that double ceiling be fitted or the thickness of the plating increased 5 mm (0·20 in) and fitted with a flush surface.

Margin Plate

908 A margin plate, if fitted, is to have a thickness throughout 20 per cent greater than required for inner bottom plating amidships. See 905.

909 In passenger ships, the inner bottom plating is to be continued out to the ship's side in such a manner as to protect the bottom to the turn of bilge. Such protection will be satisfactory if the line of intersection of the outer edge of the margin plate with the bilge plating is not lower at any part than a horizontal plane passing through the point of

intersection with the frame line amidships of a transverse diagonal line inclined at 25 degrees to the base line and cutting it at a point one half the ship's moulded breadth from the middle line.

TRANSVERSE FRAMING

Plate Floors

910 Plate floors are to be fitted at every frame in the engine room and forward as required by D 10. They are also to be fitted under the boiler bearers, bulkheads, toes of brackets to deep tank bulkhead stiffeners and in way of any change in depth of double bottom. Partial plate floors are to be fitted under the thrust seating. Floors of increased thickness are to be arranged in way of shaft brackets.

911 In ships from which cargo is to be regularly discharged by grabs, it is recommended that plate floors be fitted at every frame.

912 Except as required by 910, plate floors may be spaced not more than 3,05 m (10 ft) apart, and the shell and inner bottom plating between these floors is to be supported by bracket floors.

913 The thickness of non-watertight plate floors is not to be less than:—

$$t=0.008 D_{DB}+1~mm$$
) but need not exceed (t = $0.008 D_{DB}+0.04~in$) (15 mm (0.59 in).

914 Watertight or strengthened floors are to be fitted below, or in the vicinity of, watertight bulkheads, and their thickness is to be 2 mm (0.08 in) greater than given in 913 for non-watertight floors, but need not exceed 15 mm (0.59 in).

If the depth of the centre girder exceeds 915 mm (36 in) the floors are to be fitted with stiffeners spaced not more than 915 mm (36 in) and having a section modulus not less than:—

$$\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{D_{DB_1}}^2 \times \mathrm{h_{DB}} \times \mathrm{s_{DB}}}{185 \times 10^6} \ \mathrm{cm^3}$$

$$\left(\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{D_{DB_1}}^2 \times \mathrm{h_{DB}} \times \mathrm{s_{DB}}}{600\,000} \ \mathrm{in^3}\right)$$

where D_{DB_1} = actual depth of centre girder, in mm (in).

h_{DB} = head from top of inner bottom to top of overflow pipe, in metres (feet).

SDB = stiffener spacing, in mm (in).

The ends of the stiffeners are to be sniped.

915 Where the double bottom tanks are common with wing ballast tanks or cofferdams the scantlings of watertight floors are not to be less than required by D 19 for a tank bulkhead.

Bracket Floors

916 The bottom frames are to have a section modulus not less than:—

$$\begin{split} \frac{I}{y} &= 215 \text{S}_1 \text{sd} \times 10^{-4} \text{ cm}^3 \\ \left(\frac{I}{y} &= 3 \cdot 1 \text{S}_1 \text{sd} \times 10^{-3} \text{ in}^3 \right) \end{split}$$

where S, is unsupported span, in metres (feet).

The reversed frames are to have a section modulus not less than 85 per cent of that given above for the bottom frames and the unsupported span of bottom and reversed frames is not to exceed 2.5 m (8·2 ft).

917 The breadth of the brackets attaching the frames and the reversed frames to the centre girder and margin plate is to be three-quarters of the depth of the centre girder; the brackets are to be flanged on the unsupported edge and are to have the same thickness as the plate floors.

918 Where struts are fitted to reduce the unsupported span of the frames and reversed frames they are to have a cross-sectional area not less than:—

$$A = 0.32 \text{ Z cm}^2 \text{ for } Z \le 83.5$$

$$(A = 0.8 \text{ Z in}^2 \text{ for } Z \le 5.1)$$

$$A = 23.2 + \frac{Z}{25} \text{ cm}^2 \text{ for } Z > 83.5$$

$$(A = 3.6 + \frac{Z}{10} \text{ in}^2 \text{ for } Z > 5.1)$$

where $Z = \frac{I}{y}$ of bottom frame determined from 916.

Side Girders

919 One side girder is to be fitted when the breadth B does not exceed 20 m (65·6 ft), and for greater breadths two girders are to be fitted on each side of the centreline. The girders are to extend as far forward and aft as practicable and are to have a thickness not less than:—

$$t = 0,008D_{DB} + 1 \text{ mm}$$

 $(t = 0.008D_{DB} + 0.04 \text{ in})$

Vertical stiffeners are to be fitted at every bracket floor and are to have a depth not less than the depth of the reversed frame, or 150 mm (6 in), whichever is the greater. The thickness is to be as required for the girder.

For side girders in the forward 0,3L, see D 10.

Watertight side girders are to have a thickness 1 mm (0.04 in) greater than given above.

920 In the machinery space and thrust recess, the number and disposition of the side girders are to be such as to support the machinery effectively and to secure the necessary rigidity of structure.

LONGITUDINAL FRAMING

921 Where longitudinal framing is adopted in the double bottom (see 902) the scantlings of the longitudinals are to be determined from D 606 to D 610. Plate girders are to have a thickness determined from 927.

Plate Floors

922 Plate floors are to be fitted at every frame under the main engines and the foremost shaft tunnel bearing and at alternate frames outboard of the engine seating. They are also to be fitted under boiler bearers, bulkheads and the toes of brackets of deep tank bulkhead stiffeners.

Elsewhere, the spacing of the floors is not to exceed 3,7 m (12·1 ft), except when a notation regarding the carriage of heavy or ore cargoes is to be assigned. In this case, the spacing of floors is not to exceed 2,5 m (8·2 ft).

For spacing of floors in the forward 0,3L, see D 10.

923 The thickness of plate floors is not to be less than:—

$$t = 0.009D_{DB} + 1 \text{ mm}$$

 $(t = 0.009D_{DB} + 0.04 \text{ in})$

The thickness need not be greater than 15 mm (0.59 in) but the ratio between the depth of the double bottom and the thickness of floor is not to exceed 130. This ratio may, however, be exceeded if suitable additional stiffening is fitted.

924 Vertical stiffeners are to be fitted at each longitudinal, having a depth not less than 150 mm (6 in) and a thickness equal to the thickness of the floors.

925 For watertight floors the plate thickness is not to be less than the greater of the thicknesses determined from 914 and 923. The section modulus of the stiffeners is not to be less than required by D 1908 with ω_1 and ω_2 taken equal to 1,0 and ε_1 and ε_2 equal to 0, or as required by 924, whichever is the greater. The stiffeners are to be connected to the inner bottom and bottom longitudinals.

926 Between plate floors, transverse brackets having a thickness not less than $0.009D_{DB}$ mm (in) are to be fitted extending from the centre girder and margin plate to the adjacent longitudinal. The brackets, which are to be suitably stiffened at the edge, are to be fitted at every frame at the margin plate and those at the centre girder are to be spaced not more than 1.25 m (4.1 ft).

For duct keels, see 931.

Side Girders

927 One side girder is to be fitted where the breadth B exceeds 14 m (46 ft) and two girders are to be fitted on each side of the centreline where B exceeds 21 m (69 ft). When a notation regarding the carriage of heavy or ore cargoes is to be assigned the spacing of side girders is not to exceed 3.7 m (12·1 ft).

The girders are to extend as far forward and aft as practicable and are to have a thickness not less than:—

t
$$0075D_{DB} + 1 \text{ mm}$$

(t = $0.0075D_{DB} + 0.04 \text{ in}$)

Watertight side girders are to have a thickness 1 mm (0.04 in) greater than given above and stiffeners are to be in accordance with 914.

For side girders in the forward 0,3L, see D 10.

- 928 The longitudinal girders under the main machinery are to extend for the full length of the machinery space and are to be carried aft to support the foremost shaft tunnel bearing. This extension abaft the after engine room bulkhead is to be at least three transverse frame spaces. Forward of the engine room the girders are to be tapered off over three transverse frame spaces and are to be efficiently scarphed into the longitudinal framing system.
- 929 A vertical stiffener is to be arranged midway between floors when these are spaced more than two frame spaces apart. The stiffeners are to have a depth not less than 100 mm (4 in) and a thickness equal to the girder thickness.
- 930 Where, at the ends of the ship, the longitudinal system of framing is replaced by a transverse system, adequate arrangements are to be made to avoid abrupt discontinuities.

GENERAL

Duct Keels

931 Where duct keels are arranged, the side plates are to have a thickness not less than 1 mm (0.04 in) greater than required by 919. The sides are, in general, not to be spaced more than 1,83 m (6 ft) apart. The inner bottom and bottom shell within the duct keel are to be suitably stiffened, and continuity of floors is to be maintained.

Increased Thicknesses in Engine Rooms

932 In engine rooms the thickness of the inner bottom plating is not to be less than:—

$$t = 0.0015 \sqrt[4]{\text{Ld (s + 660) mm}}$$

(t = 0.000 85 $\sqrt[4]{\text{Ld (s + 26) in}}$)

Manholes and Lightening Holes

933 Sufficient holes are to be cut in the inner bottom floors and side girders, to provide adequate ventilation and

access to all parts of the double bottom. The edges of all holes are to be smooth. The size of opening should not, in general, exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes is to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions. The requirements of 945 and 947 regarding area of floor and girder are also to be complied with where applicable.

934 Where manhole covers are attached by bolts to the inner bottom plating, doubling rings are to be fitted to take the fastenings of the covers. Manhole covers which project above the inner bottom plating are to be adequately protected.

Ships Loading and Discharging Aground

935 It is recommended that the bottoms of ships intended to load or discharge aground be additionally strengthened in order to withstand the stresses to which they may be subjected.

Longitudinal Subdivision

936 If oil fuel is to be carried in double bottoms, holes are not to be cut in the centre girder except in the forward and after tanks, and elsewhere where tanks are narrow due to subdivision. When timber load lines are to be assigned, double bottom tanks within the midship half-length are to have adequate longitudinal subdivision.

The centre girder need not be tested.

Pumping and Drainage

937 The arrangements are to be in accordance with the requirements of Chapter E. Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suctions, taking into account the pumping rates required.

Testing

938 Each compartment is to be tested on completion with a head of water representing the maximum pressure which could be experienced in service. Alternatively, air testing in accordance with D 5202, excluding the structural test, may be carried out.

Cross-references

939 For additional stiffening under heels of pillars, see D 1408.

For strengthening of bottom forward, see D 10.

For compartments carrying oil fuel or lubricating oil, see D 1926 and D 1931.

For reserve feed water compartments, see E 710.

CARRIAGE OF HEAVY OR ORE CARGOES WITH SPECIFIED OR ALTERNATE HOLDS EMPTY

940 Where a notation regarding the carriage of heavy or ore cargoes, with specified or alternate holds empty, is to be assigned, the following requirements are to be complied with. Alternatively, the scantlings may be assessed by direct calculation using an agreed procedure.

Symbols

941 W = double bottom loading, in tonne/m² (ton/ft²), and is to be taken as:—

W = 0,68d
$$\left(W - \frac{d}{52 \cdot 5} \text{ British}\right)$$
 for full holds, and 1,02d $\left(\frac{d}{35} \text{ British}\right)$ for empty holds, where W is as defined in 905.

- b = span of floors, in metres (feet), measured to intersection of hopper side or ship's side, and tank top.
 - L = length of hold, in metres (feet), measured between bulkhead stools, where fitted, at the level of the tanktop on the centreline.
- S₁ = spacing of floors, in metres (feet).
- S₂ = half the distance between girders adjacent to the girder in question, in metres (feet).
- $\alpha = \frac{l}{b}$ and is not to be taken as less than 0,5 nor greater than 1,5.

$$\alpha_{\rm c} = 1,15 - 0,275 k_1$$

$$\begin{aligned} \mathsf{k_1} &= \frac{\mathsf{p^3}}{\mathsf{p^3} + 305\mathsf{q^2}\alpha} \; \left(\mathsf{k_1} = \frac{\mathsf{p^3}}{\mathsf{p^3} + 1000\mathsf{q^2}\alpha} \; \mathrm{British} \right) \\ &\quad \text{Where there is no hopper side tank, } \; \mathsf{k_1} \; \mathrm{is \ to \ be} \\ &\quad \text{taken as zero and if the slope of the hopper side} \\ &\quad \mathrm{is \ less \ than \ 30^\circ \ to \ the \ horizontal \ the \ value \ of \ \mathsf{k_1}} \\ &\quad \mathrm{will \ be \ considered.} \end{aligned}$$

$$k_2 = k_1 (0.205 - 0.024\alpha) + 0.312\alpha + 0.034$$

when $0.5 < \alpha \le 1.0$

or
$$k_1 (0.349 - 0.168\alpha) + 0.168\alpha + 0.178$$

when $1.0 < \alpha \le 1.5$

$$k_3 = 0.192\alpha + 0.148 - k_1(0.192\alpha - 0.092)$$

when $0.5 < \alpha \le 1.0$

or
$$0.04\alpha + 0.30 - k_1 (0.04\alpha + 0.06)$$

when $1.0 < \alpha \le 1.5$

- p = girth of hopper side tank, including hopper side and double bottom height, in metres (feet).
- q = depth of double bottom, in metres (feet). Where the tank top slopes from the side to the centreline, q is to be taken as the least depth plus three-quarters of the rise.

Notes. q may be taken initially as derived from 904.

Where this height of double bottom is increased to comply with 942 or 943 successive calculations

will be required.

t = thickness of inner bottom plating (see 905 and 906) or bottom shell plating, whichever is the least, in mm (in). Where high tensile steel is fitted the equivalent mild steel thickness is to be used.

The proportion of the doul tottom load carried by the transverse bulkhead is:—

$$\frac{k_3}{k_2 \frac{l}{b} + k_3}$$

The actual value of $\frac{l}{b}$ should be used ignoring the upper and lower limits in the definition of α .

942 The depth of centre girder is not to be less than required by 904 or the following, whichever is the greater:—

$$\frac{CWb^2P}{t}$$
 mm (in)

where
$$P = 0.054\alpha - k_1 (0.0349\alpha - 0.0134) - \frac{\delta}{100}$$

$$c = 89$$

 $\delta = 0$ when $\alpha \geqslant \alpha_c$

$$C = 114,5$$
 when

$$\delta = 5.55 k_1 (\alpha - 0.6)^2 + 5.63 (\alpha - 0.7)^2 (1 - k_1)$$

or in British units:-

$$\begin{array}{ccc}
c = 0.14 \\
\delta = 0
\end{array}$$
 when $\alpha \geqslant \alpha_c$

$$\begin{array}{l}
c = 0.18 \\
\delta = 5.55 k_1 (\alpha - 0.6)^2 + 5.63 (\alpha - 0.7)^2 (1 - k_1)
\end{array}$$
when
$$\alpha < \alpha_0$$

943 The depth of double bottom is to be such that the depth of floor at the hopper side tank is not less than:—

$$\begin{split} &\frac{89 \; \text{Wb}^2 \text{k}_1}{t} \; \left(\frac{0.0892 \; \alpha^3}{0.283 \; + \; \alpha^3} \right) \, \text{mm} \\ &\left(\frac{0.14 \; \text{Wb}^2 \text{k}_1}{t} \; \left(\frac{0.0892 \; \alpha^3}{0.283 \; + \; \alpha^3} \right) \; \text{in} \, \right) \end{split}$$

944 When the depth of the hopper side tank derived from 943 exceeds that required by 942 the inner bottom plating may be sloped, but the height at the centreline is not to be less than required by 904 or 942. Alternatively, the double bottom may have the height required by 904 or 942 and the thickness of the inner bottom plating or bottom shell (or both) is to be increased in way of the hopper side

tank so that the requirement of 943, using the increased thickness, is satisfied. The increased thickness is to extend 610 mm (24 in) outboard of the hopper side knuckle and b metres (ft) inboard of the knuckle and over the length of the hold concerned.

945 Plate floors are to be spaced not more than 2,5 m (8·2 ft) and are to have a thickness giving a net sectional area (excluding openings) at the hopper side of:—

0,89S₁wbk₂ cm² (0·14S₁wbk₂ in²) for the middle half-length of the hold.

 $0,635S_1$ wbk₂ cm² ($0.10S_1$ wbk₂ in²) for the quarter-length of the hold at each end.

The net sectional area (excluding openings) at any point y metres (feet) from the centreline, is not to be less than $\frac{2y}{b}$ times the required area at the hopper side. The thickness is not to be less than required by 923.

946 If intermediate partial floors extending from the hopper side tank to the next plate longitudinal are fitted, they are to have a thickness not less than 0,009D_{DB} mm (in) and 75 per cent of their thickness may be taken into account in assessing the area of floors required by 945.

947 Plate girders are to be spaced not more than:-

$$1,4 + \frac{L_1}{180} m$$
 $\left(4.6 + \frac{L_1}{180} ft\right)$

where L_1 = length of ship, in metres (feet), but not to be taken as greater than 215 m (705 ft).

They are to have a thickness giving a net sectional area (excluding openings) at the bulkheads of:—

0,89S₂wbk₃ cm² (0·14S₂wbk₃ in²) for the middle half-breadth of the hold,

0,635S₂wbk₃ cm² (0·10S₂wbk₃ in²) for the quarterbreadth of the hold at each side.

The net sectional area (excluding openings) at any point \times metres (feet) forward or aft of the mid-length of the hold is not to be less than $\frac{2\times}{l}$ times the required area at the bulkheads. The thickness is not to be less than required by 927.

948 If intermediate partial plate girders extending from the bulkhead to the next plate floor are fitted, they are to have a thickness not less than $0.009D_{DB}$ mm (in) and 75 per cent of their thickness may be taken into account in assessing the area of girders required by 947.

Section 10

STRENGTHENING OF BOTTOM FORWARD

Symbols

1001 L₁ = length of ship, in metres (feet), but need not exceed 215 m (705 ft).

Cb = block coefficient at load draught.

S = frame or longitudinal spacing, in mm (in)

S_b = Standard frame spacing in mm (in) i.e.,

(i) forward of 0,2L from fore perpendicular:—

as required by D 705 and D 706,

(ii) aft of 0,2L from fore perpendicular:—

$$\frac{L_1}{0.6}$$
 + 510 mm $\left(\frac{L_1}{50}$ + 20 in $\right)$

Extent

1002 The bottom forward is to be strengthened for the following extent except when the ship is designed so that a ballast draught forward of 0,04L₁ can be achieved:—

C_b of 0,70 or under — between 0,05L and 0,3L from forward

 C_b of 0,80 or over — between 0,05L and 0,25L from forward

At intermediate C_b, the extent may be obtained by interpolation.

Bottom Framed Longitudinally

- 1003 (a) Longitudinal spacing is to be in accordance with D 704 and D 705.
 - (b) Plate floors are to be fitted on alternate frames and are to have scantlings not less than required by D 923.
 - (c) Bottom longitudinals are to have scantlings in accordance with D 606 using a minimum span of 1,85 m (6·1 ft).
 - (d) Side girders are to be fitted not more than 2,1 m (6.9 ft) apart and are to have scantlings required by D 927.

Bottom Framed Transversely

- 1004 (a) Frames are to be spaced in accordance with D 704, D 705 and D 706.
 - (b) Plate floors are to be fitted at every frame and are to have scantlings not less than required by D 913.

- (c) Side girders are to be fitted not more than 2,2 m (7.25 ft) apart and are to have scantlings required by D 919.
- (d) Half-height side girders are to be fitted not more than 1,1 m (3.63 ft) apart and are to have scantlings not less than required by D 919. They are to extend as far forward as practicable.

Shell Plating

1005 When the ship is designed so that a ballast draught forward of 0,04L₁ can be achieved, no increase in the thickness of shell plating is required.

When the ballast draught forward is $0.03 L_1$ or less, the thickness of the strakes wholly or partly covering the flat of bottom within the region defined in 1002 is not to be less than:—

$$t=0.092L_1+7\sqrt{\frac{s}{s_b}}\;mm$$

$$\left(t = 0.0011 L_1 + 0.276 \sqrt{\frac{s}{s_b}} \text{ in}\right)$$

For intermediate draughts the thickness is to be obtained by interpolation between the above value and the tapered thickness. For this purpose, the nominal thickness at 0,2L from amidships for a ballast draught of 0,04L₁ may be taken as that required by D 504 (a) or (b) as appropriate, using the minimum spacing of

$$\frac{L_1}{0.6} + 510 \text{ mm}$$
 $\left(\frac{L_1}{50} + 20 \text{ in}\right)$

(d in the formulæ being the load draught) and if the spacing differs from that given in 1001 the tapered thickness is to

be corrected in the ratio
$$\sqrt{\frac{s}{s_b}}$$
.

The midship thickness of the strakes referred to above is to be carried forward to the increased plating.

The thickness of the keel plate is not to be less than that of the adjoining plating.

1006 If intermediate stiffening is fitted, the thickness of the bottom shell plating may be 80 per cent of that required by 1005 but is not to be less than the normal taper thickness.

General

1007 Floors and girders are to be connected to the shell by continuous welding, and drain holes are to be kept to a minimum.

Section 11

PANTING

Symbols

1101 L = length of ship in metres (feet).

L₁ = length of ship, in metres (feet), but need not be taken greater than 215 m (705 ft).

B₁ = moulded breadth, in metres (feet), but need not be taken greater than 32 m (105 ft).

\(\lambda = \text{vertical spacing, in metres (feet), of stringers and panting beams.

h = vertical distance, in metres (feet), from the stringers to the line of the deck at side amidships.

S = horizontal spacing of beams, in metres (feet).

S = span of beams, in metres (feet), measured from the flange of the stringer, or from half the distance between the edge of the stringer and the inboard side of the framing when the stringer is unflanged, to the centreline support, or to the opposite span point where no centreline support is provided.

General

1102 The structure is to be strengthened to resist panting for 0,15L from the fore end, and abaft the after peak bulkhead.

Forward of the Collision Bulkhead

1103 Tiers of beams to be spaced not more than 2 m (6.56 ft) apart vertically are to be fitted to alternate frames in the fore peak tank, or below the lowest deck above the waterline if the peak tank is small, and are each to have a cross-sectional area not less than:—

$$A = 2.5B_1 - \frac{L_1}{25} \text{ cm}^2$$
 $\left(A = 0.118B_1 - \frac{L_1}{530} \text{ in}^2\right)$ (1)

In addition, the least moment of inertia of any beam is not to be less than:—

$$I = lhsS^2 cm^4$$
 $\left(I = \frac{lhsS^2}{15 820} in^4\right)$ (2)

Alternatively, perforated flats may be fitted in lieu of panting beams. The arrangement and scantlings of these flats are to be as required by D 5417 and D 5439 (1).

1104 In general, the tiers of beams are to be supported at the centreline by a partial wash bulkhead or pillars.

1105 The beams are to be connected to the side frames by brackets having a depth below the stringer, measured along the inboard side of the frame, not less than

$$\frac{150A}{t}$$
 mm $\left(\frac{1\cdot5A}{t}\text{ in}\right)$

where A = sectional area of beam, in cm² (in²), obtained from 1103,

t = thickness of bracket, in mm (in), and is to be not less than the thickness of stringer plate (see 1106).

In no case is the cross-sectional area through the throat of the bracket to be less than A.

Frames to which a beam is not fitted are to be attached to the stringer plate by brackets having the same thickness as the stringer (see 1106) and having a depth measured at the shell of half the width of the stringer plate.

1106 Stringer plates attached to the shell are to be fitted at each tier of beams, and are to have scantlings not less than:—

Width =
$$3.3L + 400 \text{ mm}$$

$$\left(\text{Width} = \frac{L}{25 \cdot 3} + 15 \cdot 75 \text{ in}\right)$$
Thickness = $\frac{2.5L}{100} + 6 \text{ mm}$

$$\left(\text{Thickness} = \frac{3L}{10000} + 0.236 \text{ in}\right)$$

Abaft the Collision Bulkhead

1107 Intercostal side stringers having the same depth as the frames, a face flat of width \bot mm $\left(\frac{\bot}{83 \cdot 5}\right)$ and the thickness required by 1106, are to be fitted in line with those forward of the collision bulkhead and are to extend aft for the distance defined in 1102; they are to be attached to the shell by welding having a weld factor of 0,35 (0.50). See Notes—Table D 32.1.

The stringers may be omitted provided the shell plating is increased by 15 per cent for vessels having a length up to and including 150 m (492 ft), and 5 per cent where the length is 215 m (705 ft) and above. For intermediate lengths, the percentage may be obtained by interpolation.

For hold frames having spans in excess of 9 m (29.5 ft), see D 708.

1108 Tank side brackets are to be fitted to all frames and the strength of the attachment of the frames to the tank side brackets is to be increased by 20 per cent above the requirements of D 733.

Abaft the After Peak Bulkhead

1109 The structure is to be efficiently stiffened by deep floors and tiers of beams in association with stringers, having scantlings required by 1103 and 1106 respectively, except that they may be spaced 2,5 m (8·2 ft) apart vertically.

In twin screw ships, the frames abaft the propeller brackets and up to the lowest deck are to be attached to the shell plating by welding having a weld factor of 0.44 (0.63). See Notes—Table D 32.1.

Special arrangements may be required in single screw ships of high speed.

If, on account of the ship's form, the unsupported length of frames exceeds 2,5 m (8·2 ft), additional stiffening may be required.

For details of welding in after peak structure, see Table D 32.1 and D 5520.

Deep 'Tween Decks

1110 In ships having deep 'tween decks, additional intercostal side stringers may be required or the thickness of the shell plating is to be suitably increased.

Cross-references

1111 For framing and webs in peaks, see D 713 and D 714.

For structure in bulbous bows, see D 5441.

Section 12

STEMS AND STERNFRAMES

Symbols

1201 L = length of ship, in metres (feet).

L₁ = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft).

d = moulded draught, in metres (feet).

V = maximum service speed, in knots, with the ship in the loaded condition.

65

Materials

1202 Steel castings are to comply with the requirements of P 5.

1203 Forgings are to comply with the requirements of P 6.

STEMS

1204 Bar stems are to have scantlings not less than:

$$A = 1.6L - 32 \text{ cm}^2$$
 $(A = 0.076L - 5 \text{ in}^2)$

where A = cross-sectional area of the stem bar in cm² (in²).

Above the load waterline the dimensions may be gradually tapered to the stem head where the area may be reduced by 25 per cent.

1205 Where the stem is constructed of shaped plates, the thickness of the plates below the load waterline is to be not less than:—

$$t = 0.083 L_1 + 5 mm$$
 $\left(t = \frac{L_1}{1000} + 0.2 in\right)$

where t = thickness of plating, in mm (in).

Above the load waterline the thickness may be gradually tapered to the stem head where it may have the same thickness as the shell at ends (see D 508).

1206 Plate stems are to be supported by horizontal webs between the decks and below the lowest deck; the unsupported length of stem plates is not to exceed 1,5 m (5 ft).

Where the curvature of the plate is large, a centreline web may be required.

For strengthening of plate stems for navigation in ice, see D 24.

For bulbous bows, see D 54.

STERNFRAMES

1207 Sternframes may be cast or forged or may be fabricated from plate.

Cast steel and fabricated sternframes are to be strengthened at intervals by transverse webs. In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii which should not, in general, be less than 50 to 75 mm (1.9 to 2.9 in) depending upon the size of the casting.

1208 All sternframes are to be efficiently attached to the ship structure and the lower part of the sternframe is to be extended forward to provide an efficient connection to the flat plate keel.

Propeller Posts

1209 The scantlings of propeller posts are to be not less than:—

(i) Fabricated propeller post

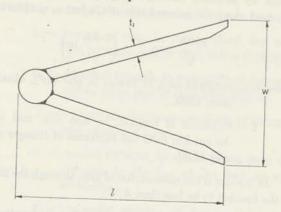


Fig. D 12.1

(ii) Cast propeller post

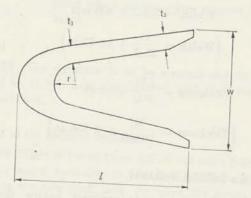


Fig. D 12.2

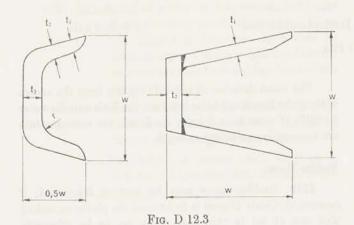
In cast propeller posts, the thickness of transverse webs is not to be less than $0.65t_2$ but need not exceed 38 mm (1.5 in).

Connection

1210 Rudder posts are to be connected to a transom floor of the same depth as that required for a double bottom floor and having a thickness 2,5 mm (0·10 in) greater than that required by D 913.

Stern Frames on Twin Screw Ships

1211 The dimensions of rudder posts which are built integral with the hull of twin screw ships are not to be less than as given below:—



$$w = 120 \sqrt{d} \text{ mm } (w = 2.60 \sqrt{d} \text{ in})$$

$$t_1 = 12 \sqrt{d} \text{ mm } (t_1 = 0.26 \sqrt{d} \text{ in})$$

$$t_2 = 15 \sqrt{d} \text{ mm } (t_2 = 0.325 \sqrt{d} \text{ in})$$

$$t_3 = 18 \sqrt{d} \text{ mm } (t_3 = 0.390 \sqrt{d} \text{ in})$$

$$r = 20 \sqrt{d} \text{ mm } (r = 0.433 \sqrt{d} \text{ in})$$

Solepiece

1212 (i) The minimum section modulus of a cast steel solepiece against transverse bending $\frac{I}{y_t}$, at any point in the solepiece at a distance × metres (feet) from the centreline of the rudder pintles or their equivalent, is not to be less than:—

$$\begin{split} \frac{I}{y_t} &= \frac{400 \text{AC (V} + 3)^2 (3x + a)}{\text{b (L} + 640)} \text{ cm}^3 \\ \left(\frac{I}{y_t} &= \frac{2 \cdot 27 \text{AC (V} + 3)^2 (3x + a)}{\text{b (L} + 2100)} \text{ in}^3\right) \end{split}$$

where a, b, c and x, in metres (feet), are as shown in Figs. D 12.4 (a), D 12.4 (b) and D 12.4 (c) and A = total area of rudder in m^2 (ft²).

- (ii) For a fabricated solepiece the minimum transverse section modulus may be taken as $0.85 \frac{I}{y_t}$.
- (iii) Where the solepiece is connected to the upper part of the sternframe by a bolted axle, the section modulus in (i) or (ii) above may be reduced by 5 per cent. Where an integral rudder post is fitted having scantlings in accordance with 1216, the section modulus in (i) or (ii) above may be reduced by 50 per cent.
- 1213 The minimum section modulus against vertical bending is not to be less than $0.50 \frac{I}{y_t}$ if the sternframe is open, not less than $0.40 \frac{I}{y_t}$ if a bolted rudder post is fitted, and not less than $0.35 \frac{I}{y_t}$ if an integral rudder post is fitted.
- 1214 In fabricated solepieces, transverse webs are to be fitted not more than 760 mm (30 in) apart; they need not be attached to the top plate.

A centreline vertical web is to be fitted where the breadth of the solepiece exceeds 900 mm ($35 \cdot 4$ in).

Propeller Boss

1215 The finished thickness of the propeller boss is not to be less than $0.1d_s + 56 \text{ mm } (0.1d_s + 2.2 \text{ in})$, where d_s is the shaft diameter, in mm (in).

Rudder Post

1216 Rudder posts supported at their lower end by a solepiece are to have a section modulus against transverse bending not less than:—

$$\frac{I}{y} = \frac{Ab (V + 3)^2}{6.8} \text{ cm}^3 \quad \left(\frac{I}{y} = \frac{Ab (V + 3)^2}{3930} \text{ in}^3\right)$$

where A and b are as defined in 1212.

Rudder Axle

1217 The design of the axle is to be such as to avoid sudden changes of section.

The diameter of an axle for a balanced type rudder is not to be less than 25d + 76 mm (0.3d + 3 in) but need not exceed 90 per cent of D_2 . The diameters D_1 and D_2 are not to be less than required by D 2208 for rudder pintles and the lengths l_1 and l_2 are not to be less than 1,2 D_1 and 1,2 D_2 respectively (see Fig. D 12.5). The bearing pressure is to be in accordance with D 2209.

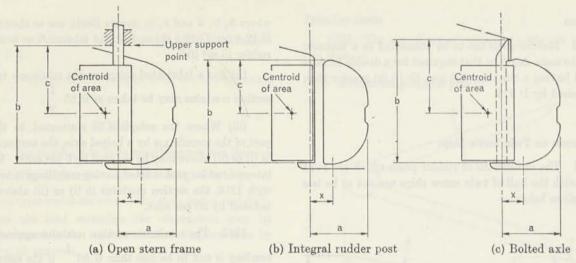


Fig. D 12.4

1218 The axle is to be connected to the hull by 6 bolts in a palm flange as shown in Fig. D 12.5. The diameter of the bolts and palm thickness is not to be less than:-

Rule axle diameter mm (in)

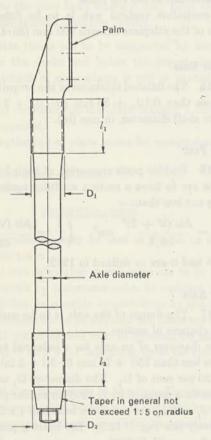


Fig. D 12.5

The mean distance of the bolt centres from the centre of the palm face is not to be less than the Rule axle diameter in 1217. If more than 6 bolts are fitted, the arrangements are to provide equivalent strength.

Rudder Horn

1219 Rudder horns may be cast or fabricated; if fabricated, Grade D steel is to be used for plates exceeding 25,5 mm (1 in) in thickness. They are to be efficiently integrated into the main hull structure and the radius at the shell connection is not to be less than 305 mm (12 in).

1220 The section modulus against transverse bending of a rudder horn when supporting a semi-spade type rudder is not to be less than:-

$$\frac{I}{y} = \frac{A (V + 3)^2 \sqrt{h^2 + 0.5g^2}}{530} cm^3$$

$$\left(\frac{I}{y} = \frac{A (V + 3)^2 \sqrt{h^2 + 0.5g^2}}{3680} in^3\right)$$

$$\left(\frac{I}{y} = \frac{A (V + 3)^2 \sqrt{h^2 + 0.5g^2}}{3680} in^3\right)$$

where A = total area of rudder, in m2 (ft2), h and g are in mm (inches). See Fig. D 12.6.

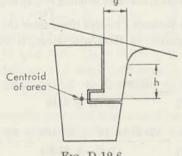


Fig. D 12.6

Propeller Clearances

1221 For recommended minimum propeller clearances for single and twin screw ships, see Chapter R (G).

Ice Strengthening

1222 For strengthening for navigation in ice, see D 24.

Section 13

DECK GIRDERS AND TRANSVERSES

Symbols

1301 S = span of girder or transverses, in metres (feet), between points of support. If an end bracket is fitted the span may be taken to a point which is half the distance between the toe of the end bracket and the support point.

b = mean width, in metres (feet), of deck (or deck and hatchway where applicable) supported by the girder or transverse.

h = load height, in metres (feet), as given in D 6 and D 8 (See also 1304, 1319 and D 25).

d_w = depth of web, in mm (in).

General

1302 For the forward 0,075 \perp of forecastle and weather decks, longitudinal girders supporting beams are not to be spaced more than 3,7 m (12·1 ft) apart, and transverses supporting deck longitudinals are not to be spaced more than 2,5 m (8·2 ft) apart. Elsewhere, transverses supporting deck longitudinals are to be spaced not more than 3,7 m (12·1 ft) apart when the length does not exceed 185 m (605 ft) and $\frac{L}{50}$ for lengths greater than 185 m (605 ft).

The web thickness of girders or transverses should not be less than:—

$$t = 9 + 0,008 \left(\frac{d_W}{50}\right)^2 mm$$

$$\left(t = 0.35 + 0.2 \left(\frac{d_W}{50}\right)^2 in\right)$$

Longitudinal Girders and Transverses supporting Deck Longitudinals

1303 The section modulus for longitudinal girders or transverses supporting deck longitudinals is not to be less than:—

$$\frac{I}{y} = 4,75 \text{ b h S}^2 \text{ cm}^3 \quad \left(\frac{I}{y} = \frac{\text{b h S}^2}{400} \text{ in}^3\right)$$

In single deck ships the section modulus of the transverses is to be increased by 15 per cent.

1304 On weather decks forward of 0,075L from the fore perpendicular, the section modulus of longitudinal girders and transverses supporting deck longitudinals is to be based on the above formula, using the h for weather deck amidships increased by 3 m (9.84 ft) and the depth of the girder or transverse is not to be less than twice that of the beam or longitudinal supported.

Weather Deck Hatch Side Girders (including Coamings)

1305 The section modulus for weather deck hatch side girders supporting transverse beams or deck transverses is not to be less than that required by (i) or (ii) below.

- (i) When the hatch side girder supports one, two or three point loads (taking a stowage rate of 1,39 m³/tonne (50 ft³/ton)) the section modulus is to be based on a stress of 1025 kg/cm² (6.5 ton/in²) assuming 100 per cent end fixity,
- (ii) When the hatch side girder supports four or more point loads from deck transverses, or an evenly distributed load:—

$$\frac{\mathrm{I}}{\mathrm{y}} = 5,\!85 \; b \; h \; S^2 \; \mathrm{cm}^3 \qquad \left(\frac{\mathrm{I}}{\mathrm{y}} = \frac{b \; h \; S^2}{325} \; \mathrm{in}^3\right) \label{eq:energy_spectrum}$$

'Tween Deck Hatch Side Girders

1306 The section modulus of 'tween deck hatch side girders supporting transverse beams or deck transverses is not to be less than that required by (i) or (ii) below.

- (i) When the hatch side girder supports one, two or three point loads (taking a stowage rate of 139 m³/tonne (50 ft³/ton)) the section modulus is to be based on a stress of 1150 kg/cm² (7·3 ton/in²) assuming 100 per cent fixity.
- (ii) When the hatch side girder supports four or more point loads from deck transverses, or an evenly distributed load:—

$$\frac{I}{y} = 5,20 \, b \, h \, S^2 \, \, \mathrm{cm}^3 \qquad \left(\frac{I}{y} = \frac{b \, h \, S^2}{365} \, \, \mathrm{in}^3 \right)$$

Hatch End Beams

1307 Where the deck is transversely framed, hatch end beams supported at the centreline and carrying hatch side coamings and longitudinal girders in line, are to have a section modulus not less than:—

$$\begin{split} &\frac{I}{y} = 19 \, K_1 \, S \, (S_1 \, b_1 \, h + S_2 \, b_2 \, h) + z_1 \, \text{cm}^3 \\ &\left(\frac{I}{y} = \frac{K_1 \, S}{100} \, (S_1 \, b_1 \, h + S_2 \, b_2 \, h) + z_1 \, \text{in}^3\right) \end{split}$$

where S = span of hatch end beam, in metres (feet). See 1301,

S, = span of hatch side girder, in metres (feet),

b₁ = mean width, in metres (feet), of deck and hatchway supported by hatch side girder,

S₂ = span of the adjacent longitudinal girder in line, in metres (feet).

b₂ = mean width, in metres (feet), of deck supported by the adjacent longitudinal girder in line,

z₁ = an increase dependent upon the constructional arrangement between the hatch openings. See 1308,

bh = breadth of hatchway, in metres (feet),

K, = a factor obtained from Table D 13.1.

TABLE D 13.1

b _h 2S	К1	
0,20	0,143	
0,30	0,177	
0,40	0,191	
0,50	0,187	
0,60	0,179	
0,70	0,169	
0,80	0,141	
0,90	0,085	
1,00	0	

1308 If there is an additional longitudinal girder situated inboard of the line of hatch side girder and between the hatches then:—

$$\begin{aligned} z_1 &= 19 \, K_1 \, S \, (S_4 \, b_4 \, h) \, \mathrm{\,cm^3} \\ \left(z_1 &= \frac{K_1 \, S}{100} \, (S_4 \, b_4 \, h) \, \mathrm{\,in^3} \right) \end{aligned}$$

where S₄ = span of the additional longitudinal girder, in metres (feet),

b₄ = mean width, in metres (feet), of deck supported by the additional longitudinal girder,

K₁ = a factor obtained from Table D 13.1 but taking b_h equal to twice the distance between the ship's centreline and the additional longitudinal girder,

1309 When the deck is framed longitudinally the hatch end beam is to have a section modulus not less than that required by (i) or (ii) below.

(i) When there are no transverses between the hatch end beam and the adjacent transverse bulkhead or equivalent support structure:—

$$\begin{split} &\frac{\mathrm{I}}{\mathrm{y}} = 19 \, \mathrm{K_1 \, S} \, (\mathrm{S_1 \, b_1 \, h}) + 2,\!37 \, \mathrm{b_3 \, h} \, \mathrm{S^2 \, cm^3} \\ &\left(\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{K_1 \, S}}{100} \, (\mathrm{S_1 \, b_1 \, h}) + \frac{\mathrm{b_3 \, h} \, \mathrm{S^2}}{800} \, \mathrm{in^3}\right) \end{split}$$

where b₃ = distance, in metres (feet), between the hatch end beam and the adjacent transverse bulkhead or equivalent support structure.

K1, S, S1 and b1 are as defined in 1307.

(ii) When there are one or more transverses between the hatch end beam and the adjacent transverse bulkhead or equivalent support structure:—

$$\begin{split} \frac{\mathrm{I}}{\mathsf{y}} &= 19 \; \mathsf{K_1} \; \mathsf{S} \; (\mathsf{S_1} \, \mathsf{b_1} \, \mathsf{h} + \mathsf{S_3} \, \mathsf{b_1} \, \mathsf{h}) \; \mathrm{cm}^3 \\ \left(\frac{\mathrm{I}}{\mathsf{y}} \; = \frac{\mathsf{K_1} \; \mathsf{S}}{100} \, (\mathsf{S_1} \, \mathsf{b_1} \, \mathsf{h} + \mathsf{S_3} \, \mathsf{b_1} \, \mathsf{h}) \; \mathrm{in}^3 \right) \end{split}$$

where S₃ = distance, in metres (feet), between the hatch end beam and adjacent transverse bulkhead or equivalent support structure,

K₁, S, S₁ and b₁ are as defined in 1307.

Inertia

1310 The moment of inertia of deck girders is not to be less than:—

$$I = K_2 \frac{I}{y} S \text{ cm}^4 (\text{in}^4)$$

where $K_2 = 2.3$ (0.275 British) for weather deck hatch side girders

1.85 (0.222 British) for other longitudinal girders,

2,8 (0.336 British) for hatch end beams,

 $\frac{I}{y}$ = Rule section modulus of the girder, in cm³ (in³).

End Connections

1311 Girders, deck transverses and hatch end beams are to have stiffened end brackets (with a suitable face flat) having the same thickness as the girder web plate. The distance from the deck to the toe of the bracket is not to be less than:—

$$150 + 52 \sqrt[3]{\frac{1}{y}} \text{ mm} \qquad \left(6 + 6.52 \sqrt[3]{\frac{1}{y}} \text{ in}\right)$$

where $\frac{1}{y}$ is the Rule section modulus of the girder, in cm³ (in³),

The horizontal arm of the bracket is not to be less than the depth of the bracket below the girder.

For welding requirements, see Table D 32.1.

Effective Flange

1312 The effective area of the attached deck plating to be included in the section modulus calculation for symmetrical and unsymmetrical girders (including weather deck hatch coamings) and box girders, is to be calculated as given in D 5304.

For minimum thickness of deck plating in association with girders, see D 414.

Details

1313 Girders of unsymmetrical section are to be supported by tripping brackets at alternate beams or equivalent; if the section is symmetrical the brackets may be four frame spaces apart. Where the ratio of the unsupported width of the girder face flat or flange to its thickness is 16 or greater, the tripping brackets are to be connected to the face flat or flange. On girders of symmetrical section tripping brackets are to be fitted on both sides when they are required to be connected to the flange. Intermediate beams are to be connected to the girder by welding or by lugs.

If the girder is not continuous between bulkheads, the part which is under the deck is to be extended beyond the end point of support for at least two frame spaces before commencing tapering off the web depth.

1314 Continuity is to be efficiently maintained over the heads of pillars, and tripping brackets fitted in way.

1315 At the corners of all hatchways supported by hatch end beams, horizontal gusset plates are to be fitted connecting the side girders to the hatch end beams. The gusset plates should taper off in the fore and aft direction over not less than one frame space; the taper outboard is to be over a similar distance and inboard not less than 450 mm (17.7 in). The thickness is to be not less than the maximum thickness of the face flats being connected.

1316 Weather deck deep hatch coamings acting as girders should be extended beyond the hatchway ends in the form of brackets, the coamings below the deck are to be effectively connected to the hatch end beams.

Where extension above the deck is not practicable, the coaming below the deck is to be extended at least two frame spaces beyond the hatch end beams.

Additional Loads

1317 Where a girder is subject to concentrated loads, such as pillars out of line, the scantlings are to be suitably increased.

Where concentrations of loading on one side of the girder may occur, the girder should be adequately stiffened against torsion.

Additional attachments may be required to meet particular local stresses.

1318 Where cargoes such as chilled meat are suspended from a deck which may be simultaneously loaded above, the scantlings of the girders are to be increased in accordance with D 603, D 605, D 807 and D 810.

Timber Deck Cargoes

1319 Where timber load lines are to be assigned, h in the foregoing sections for weather decks is to be taken as 1,5 m (5 ft) where the beam B does not exceed 15 m (49 ft) and 1,83 m (6 ft) where the beam is 18 m (59 ft) or over, with intermediate values in proportion. In single deck ships the section modulus of the transverses supporting deck longitudinals is to be increased by 40 per cent.

Grades of Steel

1320 For special steel requirements in girder webs on refrigerated ships, see D 422.

Cross-references

1321 For cantilevers, see D 15.

Section 14

PILLARS AND NON-WATERTIGHT PILLAR BULKHEADS

Symbols

1401 P = load, in tonnes (tons), supported by the pillar and is to be equal to $\frac{Sb_dh}{\rho} + P_a$ but not less than 2 tonnes (1.97 tons).

S = distance, in metres (feet), between the centres of the two adjacent spans of girder supported by the pillar.

b_d = mean width of deck, in metres (feet), including hatchway if necessary, supported by the girders.

h = head, in metres (feet), supported by pillar, obtained from D 806, D 809 and D 1304.

P_a = load, in tonnes (tons), from pillar or pillars above (zero if no pillar above).

ρ = stowage rate and is to be taken as 1,39 m³/
tonne (50 ft³/ton) unless specified otherwise.

Chapter D

A = cross-sectional area of pillar, in cm² (in²).

l = overall span of pillar, in metres (feet).

 $l_{\rm e}=$ effective span of pillar, in metres (feet), where $l_{\rm e}=0.65l$ for hold pillars and 0.8l for 'tween deck pillars.

r = minimum radius of gyration of pillar cross-section, in mm (in).

d_p = mean diameter of tubular pillar, in mm (in).

PILLARS

1402 The sectional area of pillars is not to be less than:—

$$A = \frac{P}{1,26 - 5,25 \frac{l_e}{r}} \text{ cm}^2$$
 (1)

$$\left(A = \frac{P}{8 - 0.4 \frac{l_e}{r}} \text{ in}^2\right)$$

As a first approximation, A may be taken as $\frac{P}{0.95}$ $\left(\frac{P}{6}\right)$ British and the radius of gyration estimated for a suitable section having this area. If the area calculated using this radius of gyration differs by more than 10 per cent from the first approximation, a further calculation using the radius of gyration corresponding to the mean area of the first and second approximations is to be made.

For tubular pillars the wall thickness is not to be less than:—

$$t = \frac{P}{0.04 d_p - 0.5 l_e} \text{ mm, or } \frac{d_p}{40} \text{ mm}$$
 (2)

$$\left(\mathrm{t}\,=\!\frac{\mathrm{P}}{25\cdot4\;\mathrm{d_p}-3\cdot8\;\!\ell_\mathrm{e}}\;\mathrm{in,or}\frac{\mathrm{d_p}}{40}\;\mathrm{in}\right)$$

whichever is the greater.

1403 Where pillars support eccentric loads they are to be strengthened for the additional bending moment imposed upon them.

1404 For the sides of hollow square pillars or web plates of Channel or I sections the ratio of the breadth to the thickness is not to exceed:—

$$600 \frac{l_e}{r} \quad \left(7.2 \frac{l_e}{r} \text{ British}\right) \text{ or } 55$$

whichever is the greater.

The thickness of tubular and hollow square pillars is to be not less than 7.5 mm (0.30 in).

For ordinary angle or channel sections the ratio of the breadth to the thickness of the flanges is not to exceed:—

$$200 \, \frac{l_{\rm e}}{r} \quad \left(2 \cdot 4 \, \frac{l_{\rm e}}{r} \, \, {\rm British}\right) \, \, {\rm or} \, \, 18$$

whichever is the greater.

For fabricated sections or the flanges of I section pillars the ratio of the breadth to the thickness of face plates is not to exceed:—

$$400 \frac{l_e}{r} = \left(4 \cdot 8 \frac{l_e}{r} \text{ British}\right) \text{ or } 36$$

whichever is the greater.

General

1405 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

1406 Tubular and hollow square pillars are to be attached at their heads to plates supported by brackets, flanged where necessary, in order to transmit the load effectively. Doubling or insert plates are to be fitted to the inner bottom under the heels of tubular or hollow square pillars, and to decks under large pillars.

The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding.

- 1407 At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.
- 1408 In double bottoms under widely spaced pillars, the connections of the floors to the girders and of the floors and girders to the inner bottom are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars.

Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided.

- 1409 Where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.
- 1410 Where pillars are fitted inside tanks or under watertight flats, the tensile stress in the pillar and its end connections is not to exceed 1100 kg/cm² (7 ton/in²). In general, such pillars should be of built sections.

1411 Pillars are to be fitted below deckhouses, windlasses, winches, capstans and elsewhere where considered necessary. The structure in way of the boat davits is to be strengthened.

1412 Arrangements for supporting the structure in machinery spaces will be considered.

For pillars under forecastles in tankers, see D 5437.

Timber Deck Cargoes

1413 Where timber load lines are to be assigned, the head to be used when calculating weather deck pillars is to be in accordance with D 1319.

NON-WATERTIGHT PILLAR BULKHEADS

- 1414 The thickness of bulkhead plating is not to be less than 7,5 mm (0·30 in) in holds and 6,5 mm (0·26 in) in 'tween decks.
- 1415 Stiffeners are to be spaced not more than $1500 \text{ mm} (59 \cdot 1 \text{ in})$ apart.
- 1416 Stiffeners or corrugations are not to be less in depth than 150 mm (6 in) in holds and 100 mm (4 in) in 'tween decks.
- 1417 Rolled, built, swedged or corrugated stiffeners supporting deck beams, longitudinals, girders or transverses, are to have a sectional area (including attached plating) not less than that given below for the two cases:—
 - (i) where

$$\frac{s}{t}$$
 exceeds $500 \frac{l_e}{r} \left(6.0 \frac{l_e}{r} \text{ British} \right)$

for rolled or built sections and swedges

or (ii) where $\frac{b}{t}$ exceeds

$$\frac{750\lambda}{(\lambda+0,25)} \; \frac{\textit{l}_{\rm e}}{r} \; \left(\frac{9\lambda}{(\lambda+0\cdot25)} \; \frac{\textit{l}_{\rm e}}{r} \; {\rm British} \right)$$

for symmetrical corrugations

then
$$A = \frac{P}{0.5 - 1.5 \frac{\ell_e}{r}} \text{ cm}^2$$

$$\left(A = \frac{P}{3 \cdot 18 - 0 \cdot 114 \frac{l_e}{r}} \operatorname{in^2}\right)$$

where S = stiffener spacing, in mm (in), for rolled or built sections, or breadth of flat plating for swedges, b, c, d and t are as shown in Fig. D 14.1 for symmetrical corrugations, measured in mm (in),

$$\begin{split} \lambda &= \frac{b}{c} \\ r &= 10 \sqrt{\frac{I}{A}} \ mm \ \left(\ r = \sqrt{\frac{I}{A}} \ in \right) \end{split}$$

for rolled or built sections and swedges

where I = inertia in cm⁴ (in⁴) of stiffener with 610 mm (24 in) of attached plating,

A = area in cm² (in²) of stiffener with attached plating of breadth S,

$$r = d\sqrt{\frac{3b+c}{12(b+c)}}$$
 for symmetrical corrugations.

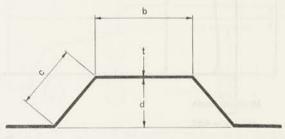


Fig. D 14.1

For a first approximation, A may be taken as $\frac{P}{0,4} \left(\frac{P}{2 \cdot 5} British \right)$.

Where $\frac{s}{t}$ and $\frac{b}{t}$ do not exceed the above limits, the area of stiffener and total attached plating is to be in accordance with 1402.

1418 The connections of bulkheads to deck and inner bottom are to be in accordance with Table D 32.1.

Section 15

CANTILEVERS

1501 This Section gives the required scantlings for cantilevers and their supporting frames. Section moduli for cantilevers not at hatch sides are given in 1503. Section moduli for hatch side cantilevers are given in 1504 and 1505. The remaining paragraphs in this section refer to all cantilevers.

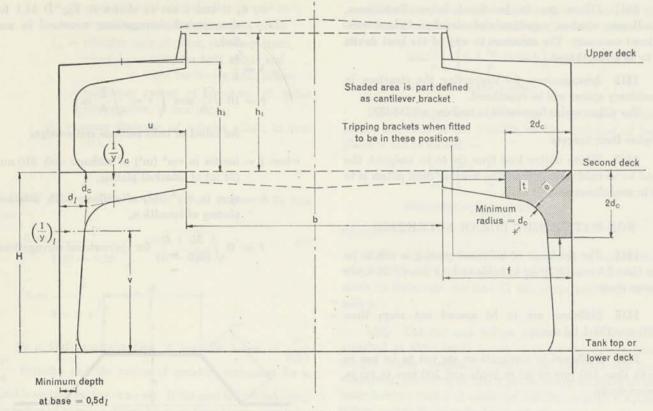


Fig. D 15.1

Symbols 1502

 $\left(\begin{matrix} I \\ y \end{matrix}\right)_2$, $\left(\begin{matrix} I \\ y \end{matrix}\right)_3$ = mean of section moduli, in cm³ (in³), of hatch end beams calculated for

the positions shown in Fig. D 15.2. $\binom{\underline{I}}{y} s_1 = \underset{\text{hatch side girder.}}{\operatorname{section modulus, in cm}^3} \text{ (in}^3), \text{ of }$

$$\begin{split} \left(\frac{I}{y}\right)_{S_2} &= \text{mean of section moduli, in cm}^3 \text{ (in}^3), \\ &\text{of longitudinal girders in line with} \\ &\text{hatch side girder. } \left(\frac{I}{y}\right)_{S_2} \text{ is not to be} \\ &\text{taken greater than } \left(\frac{I}{y}\right)_{S_1}. \end{split}$$

 $\beta = \frac{c}{l}$

 $\rho=$ stowage rate, and is to be taken as 1,39 m³/tonne (50 ft³/ton) unless specified otherwise.

$$\mathsf{E} = \frac{4}{\mathsf{n}+1} \left[\left. \left\{ \left(\frac{\mathrm{I}}{\mathsf{y}} \right)_{\mathtt{i}} + \left(\frac{\mathrm{I}}{\mathsf{y}} \right)_{\mathtt{a}} \right\} \right. \\ \left. + \frac{2\mathsf{u}}{\mathsf{b}} \left\{ \left(\frac{\mathrm{I}}{\mathsf{y}} \right)_{\mathtt{a}} + \left(\frac{\mathrm{I}}{\mathsf{y}} \right)_{\mathtt{a}} \right\} \right. \right]$$

where centreline bulkheads or centreline pillars are fitted.

$$\mathsf{E} = \frac{4}{\mathsf{n}+1} \left[\left(\frac{\mathsf{I}}{\mathsf{y}}\right)_{\mathsf{1}} + \left(\frac{\mathsf{I}}{\mathsf{y}}\right)_{\mathsf{2}} \right] \text{ where there is no support}$$
 at the centreline.

$$\begin{split} & \mathbf{G} = \frac{7 u}{(\mathsf{n}+1)\,\mathsf{c}}\, \left[\left(\frac{\mathrm{I}}{\mathsf{y}} \right)_{\mathsf{S}_1} + \left(\frac{\mathrm{I}}{\mathsf{y}} \right)_{\mathsf{S}_2} \right] \\ & \mathbf{G}_{_1} = \frac{3,5\,u}{\mathsf{s}}\, \left(\frac{\mathrm{I}}{\mathsf{y}} \right)_{\mathsf{S}_1} \end{split}$$

M = bending moment in tonnes metres (tons ft) due to the load supported by a single cantilever. This bending moment is to be calculated about an axis distant u from hatch side, and for hatch side cantilevers with uniformly distributed loading it will be

$$\frac{su}{2\rho}\;(h_1\,b+h_2\,u).$$

c = distance, in metres (feet), between hatch end beams.

$$Z = \frac{f}{u} \begin{pmatrix} I \\ v \end{pmatrix}_{c}$$

 $h_i = \text{mean height, in metres (feet), of}$ cargo space above hatchway. (At weather decks, see D 806).

h₂ = mean 'tween deck height, in metres (feet), clear of hatchway. (At weather decks, see D 806).

l = distance, in metres (feet), between transverse bulkheads. Where there is no bulkhead between hatchways, l is to be measured to a point midway between hatchways.

n = number of cantilevers between the hatch end beams.

s = cantilever spacing, in metres (feet).

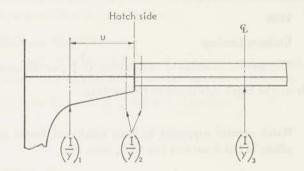
 A_f = sectional area, in cm² (in²), of cantilever bracket face plate.

d = web depth of cantilever or frame, in mm (in). $d_c = \text{root depth, in mm (in), of cantilever,}$ as indicated in Fig. D 15.1.

b, f, u, v and H are measured in metres (feet), as shown in Figs. D 15.1 and D 15.3.

t, d/ and e are measured in mm (in), as shown in Fig. D 15.1.

Note: The dimensions shown in Fig. D 15.1 are for calculating the second deck cantilevers. When other decks are being considered the deck indicated as "2nd Deck" is to be considered as the deck in question.



 $\left(\frac{1}{y}\right)_2$ is the smaller modulus of the sections adjacent to the hatch side Fig. D 15.2

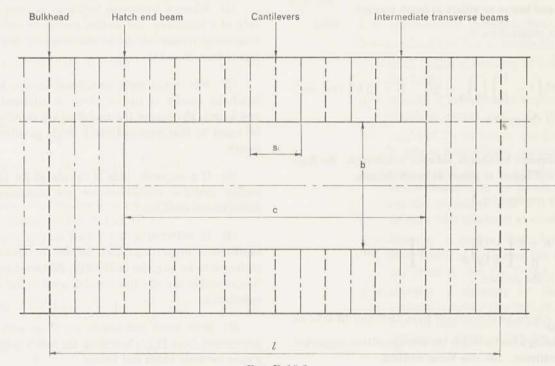


Fig. D 15.3

Cantilevers not at Hatch Sides

1503 The section modulus of cantilevers $(\frac{I}{y})_{0}$ at distance u from the outer end is not to be less than:—

$$\left(\frac{I}{v}\right)_{O} = 85 \text{M cm}^3 \quad (1.6 \text{M in}^3)$$

The section modulus of supporting frames or stiffeners at distance \mathbf{v} from the lower end is not to be less than:—

$${I \choose y}_{\vec{l}} = \frac{v}{H} \left[\frac{f}{u} {\left(\frac{I}{y} \right)}_{\mathbf{O}} - {\left(\frac{I}{y} \right)}_{\mathbf{U}} \right] \, \mathrm{cm}^3 \, (\mathrm{in}^3)$$

Hatch Side Cantilevers

1504

(i) Uniform Loading

The section modulus of cantilevers, $\begin{pmatrix} I \\ y \end{pmatrix}_{C}$, at distance u from the hatch side is not to be less than-:—

A Hatch corners supported by Rule hatch end beams or pillars at hatch corners (see 1505, Note (5)).

$$\binom{I}{y}_{C} = 0.9 \left(\frac{I}{y}\right)_{O} - G \text{ cm}^{3} (\text{in}^{3})$$

B Transverse bulkheads between hatchways. No Rule hatch end beams or pillars at hatch corners.

As required by A

or

$$\frac{n+1}{n} \left[0{,}45 \left(1+\frac{1}{\beta}\right) \left(\frac{I}{y} \right)_{\!\! O} - \beta G - (1-\beta) \, E \right] \, \mathrm{cm}^3 \ (\mathrm{in}^3)$$

whichever is the greater.

O No transverse bulkheads between hatchways. No Rule hatch end beams or pillars at hatch corners.

As required by A

or

$$\frac{\mathsf{n}+1}{\mathsf{n}}\left[\frac{1}{\beta}\binom{I}{\mathsf{y}}_{\mathsf{O}}-0.5\;\mathsf{E}\right]\;\mathrm{cm}^{3}\;(\mathrm{in}^{3})$$

whichever is the greater.

(I) o is to be determined from 1503 and M is to be calculated using a load which is the average of that supported by each cantilever. See also Notes to 1505.

(ii) Concentrated Loading

The requirements in 1504(i) are based on the assumption that cantilevers are approximately equally spaced and equally loaded. Where a particular cantilever is subjected to concentrated loading, its modulus is to be that given by the following formula or as required by 1504(i) whichever is the greater:—

$$\left(\frac{\mathrm{I}}{\mathrm{y}}\right)_{\mathrm{C}} = \left(\frac{\mathrm{I}}{\mathrm{y}}\right)_{\mathrm{O}} - \mathsf{G}_{\scriptscriptstyle{\mathrm{I}}} \ \mathrm{cm}^{\scriptscriptstyle{\mathrm{3}}} \ (\mathrm{in}^{\scriptscriptstyle{\mathrm{3}}})$$

where $\left(\frac{1}{y}\right)_0$ is to be determined from 1503, and M is to be calculated using the particular load on the cantilever being considered.

Frames supporting Hatch Side cantilevers

1505 The section modulus, at a distance v above the tank top or lower deck, of frames supporting cantilevers is not to be less than:—

$$\frac{\left(\frac{I}{y}\right)_{\vec{l}} + \frac{v}{H} \left[\frac{f}{u} \left(\frac{I}{y}\right)_{C} - \left(\frac{I}{y}\right)_{U}\right] \text{ cm}^{3} \text{ (in}^{3})}{\text{where } \left(\frac{I}{y}\right)_{C} \text{ is to be determined from 1504.} }$$

Notes

The following Notes apply to 1504 and 1505:-

- (1) Where a transverse bulkhead is fitted at one end only of a hatchway, the section moduli of cantilevers and supporting frames are to be the mean of the values obtained from B and C.
- (2) Where the only cantilevers in the length of a hatchway consist of two or three on adjacent frames at mid-length, the sum of the moduli of the cantilevers should be equal to that required for a single cantilever at mid-length.
- (3) If a negative value is calculated for the required section modulus, cantilevers are not necessary with the arrangement considered.
- (4) In calculating the actual section modulus of a cantilever or supporting frame, the effective area of attached plating is to be as given in D 5304. Intermediate beams or frames within the effective breadth may be included in the calculation.
- (5) Rule hatch end beams are those with scantlings determined from D 13, assuming the hatch side girder has a span between hatch end beams.

GENERAL

1506 The section modulus of side frames supporting cantilevers is not to be less than that required by D 7 for side frames in the same position. The section modulus of cantilever beams is not to be less than that required by D 8 for beams in the same position. The scantlings of pillars or pillar bulkhead stiffeners supporting cantilevers must also comply with D 14.

The modulus of hatch side coamings or girders is not to be less than that required by D 1305 or D 1306 taking the span between the cantilevers.

Inertia

1507 The moment of inertia of cantilever beams at distance u from the hatch side or end of the cantilever is not to be less than:—

$$I = 9 \ \mathsf{u} \ {\textstyle \left(\frac{I}{\mathsf{y}}\right)_{\mathbf{C}}} \ \mathrm{cm}^{4} \quad \ \Big(1 = 1 \cdot 08 \ \mathsf{u} \ {\textstyle \left(\frac{I}{\mathsf{y}}\right)_{\mathbf{C}}} \ \mathrm{in}^{4}\Big).$$

 $\left(\frac{I}{y}\right)_{C}$ is the Rule section modulus at the same position.

Cantilever Brackets

1508 The minimum thickness, t of cantilever brackets and the minimum sectional area, A_f, of bracket face plates are to extend at least to the limits of the shaded portion shown in Fig. D 15.1 and are to be:—

(a) when tripping brackets are not fitted,

$$t = 0.0075 d_c + 5 mm$$
 (1)
 $(t = 0.0075 d_c + 0.20 in)$

$$A_{f} = \frac{27Z}{e} \left(1 - \frac{e}{1420 \, f} \right) - \frac{et}{300} \, \mathrm{cm}^{2}$$

$$\left(A_{f} = \frac{2 \cdot 7Z}{e} \left(1 - \frac{e}{17f} \right) - \frac{et}{3} \, \mathrm{in}^{2} \right)$$

$$(2)$$

(b) when tripping brackets are fitted at the positions indicated in Fig. D 15.1,

$$t = 0,0075 d_c + 5 mm$$
 (3)
 $(t = 0.0075 d_c + 0.20 in)$

$$A_{f} = \frac{20Z}{e} \left(1 - \frac{e}{1420f} \right) - \frac{et}{200} \text{ cm}^{2}$$

$$\left(A_{f} = \frac{2Z}{e} \left(1 - \frac{e}{17f} \right) - \frac{et}{2} \text{ in}^{2} \right).$$

$$(4)$$

1509 In general, the radius at the throat of the cantilever is not to be less than d_c as indicated in Fig. D 15.1.

1510 Cantilever and supporting frame face plates may be gradually tapered from the limits of the shaded portion shown in Fig. D 15.1, and the web depth of supporting frames may be tapered to a minimum of $\frac{\mathrm{d} l}{2}$ at the base.

Web Stiffening

1511 Where the web thickness of cantilevers or supporting frames is less than $\frac{d}{60}$, transverse web stiffeners should be fitted spaced approximately 1,5d apart. Where stiffeners are fitted parallel to the face plates, the stiffening arrangements will be considered.

Minimum Web Thickness

1512 The web thickness of cantilevers and supporting frames outside the limits of the cantilever brackets, as shown in Fig. D 15.1, is not to be less than $\frac{d}{85}$.

Section 16

LONGITUDINAL STRENGTH IN WAY OF ERECTIONS

Symbols

1601 L = length of ship, in metres (feet).

B = moulded breadth, in metres (feet).

l = mean length of erection, in metres (feet). See 1604.

b = breadth of lowest tier of erections at midlength, in metres (feet). See 1605.

h = height of lowest tier of erections at midlength, in metres (feet), measured at side.

a = area, in cm² (in²), of continuous longitudinal material in the lowest tier of the erection (openings need not, in general, be deducted) measured at amidships.

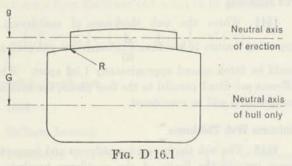
g = distance, in metres (feet), between the neutral axis of the lowest tier of erection and point R. See Fig. D 16.1.

e = modulus of elasticity for the erection material in kg/cm² (ton/in²). $(2.1 \times 10^6 \text{ kg/cm}^2 (13 500 \text{ ton/in}^2) \text{ for steel and } 0.7 \times 10^6 \text{ kg/cm}^2 (4500 \text{ ton/in}^2) \text{ for aluminium alloy}.$

E = modulus of elasticity for the hull material, in kg/cm² (ton/in²).

A = area of continuous longitudinal material in the main hull measured at amidships in cm² (in²).

G = distance, in metres (feet), between the neutral axis of the hull and point R. See Fig. D 16.1.



Where several tiers of erections are fitted, the calculation to determine their efficiency is to be carried out firstly for the lowest tier only and a correction applied later for the effect of tiers above. See 1607.

Application

1602 In this Section the term "erection" includes both superstructures and deckhouses.

1603 Where erections extending within 0,5L amidships and having lengths exceeding $42 - \frac{30b}{B}$ m $\left(137.8 - \frac{98.4b}{B}\text{ ft}\right)$ are fitted, the requirements of this Section are to be complied with in addition to those of D 17.

Tiers of Differing Length

1604 The length l of the erection to be used in the calculation is to be taken as the weighted mean value of those tiers whose length exceeds $0.7l_1$, as given below.

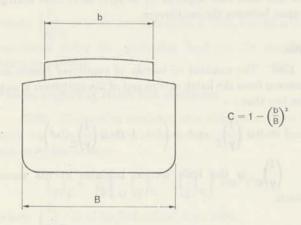


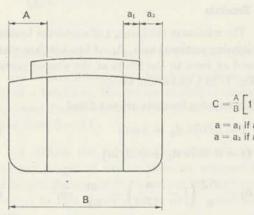
(i) when
$$l_2$$
, l_3 and $l_4 > 0.7 l_1$,
$$l = \frac{8 \, l_1 + 4 \, l_2 + 2 \, l_3 + l_4}{15}$$

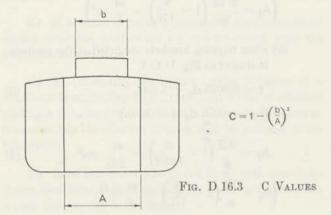
(ii) when
$$l_4 < 0.7 l_1$$
 and l_2 and $l_3 > 0.7 l_1$,
$$l = \frac{4 l_1 + 2 l_2 + l_3}{7}$$

(iii) when
$$l_4$$
 and $l_3 < 0.7l_1$ and $l_2 > 0.7l_1$,
$$l = \frac{2l_1 + l_2}{3}$$

Any parts of the erection extending beyond the fore or aft perpendiculars are to be neglected.







Tiers of Differing Breadth

1605 Upper tiers are not, in general, to be included in the calculation if their breadths are more than 3,7 m (12·1 ft) less than that of the lowest tier. If, however, upper tiers having less breadth are effectively supported by partial bulkheads or strong web frames below, spaced not more than 9,0 m (29·5 ft) apart, they may be included in the calculation. When the breadth of an upper tier is less than $\frac{b}{2}$ or $\frac{B}{3}$, whichever is smaller, its effect is negligible and it need not be included in the calculation.

Calculation Method

1606 The flexibility factor, ψ , for the deck upon which the lowest tier of the erection stands, is to be calculated from the following formula:—

$$\psi = 12 \; \text{KC}^2 \; \frac{t}{h} \; \frac{e}{E} \quad \left(\psi = 1000 \; \text{KC}^2 \; \frac{t}{h} \; \frac{e}{E} \; \text{British} \right)$$

where C = a constant depending upon the $\frac{b}{B}$ ratio or the number and location of longitudinal bulkheads fitted (if any) (see Fig. D 16.3),

K = a constant depending upon the number of transverse bulkheads in the hull under the erection, and is to be obtained from Table D 16.1 and Notes,

t = thickness of the errection side plating in mm (in).

Note. Continuous longitudinal bulkhead to be at least 6.0 m (19.7 ft) longer than the lowest tier of the erection.

1607 The basic erection efficiency factor η_1 is obtained from Fig. D 16.5 which is based upon the following standard ratios:—

$$\frac{b}{b} = 5,0$$

$$\frac{g}{G} = 0.35$$

$$\frac{\text{ae}}{\text{AE}} = 0,10$$

 η_1 is then corrected for actual values of these ratios using Figs. D 16.6, D 16.7 and D 16.8, i.e., if $\frac{b}{h}$ differs from 5,0, Fig. D 16.6 is entered with the value of η_1 and a corrected value η_2 obtained. This value η_2 is then corrected using Fig. D 16.7 for variations in $\frac{g}{G}$ and η_3 obtained. Similarly η_4 is obtained from Fig. D 16.8.

A factor f is derived from Fig. D 16.9 and the final erection efficiency factor η_f is given by:—

$$\eta_f = \eta_4 f$$

For a single tier erection f = 1.

TABLE D 16.1-K VALUES

Number of transverse bulkheads in the hull under the erection.	One effective transverse bulkhead directly under the erection ends, or situated close to the ends and within the length of the deckhouse.	No effective trans verse bulkhead unde ends of erection.	
0		300,0*	
1	-	175,0	
2	75,0	100,0	
2 3 4 5 6 7 8	45,0	58,0	
4	27,1	38,0	
5	18,3	27,5	
6	13,3	19,8	
7	9,8	14,2	
8	7,2	10,4	
9	5,2	7,6	
10	4,0	4,9	

NOTES

- *225 if deck transverses are fitted under the erection throughout.
 If there is a transverse bulkhead under one end only, the mean
- If there is a transverse bulkhead under one end only, the mean value obtained from the 2nd and 3rd columns is to be used in the calculation.

1608 The following diagram is to be constructed:-

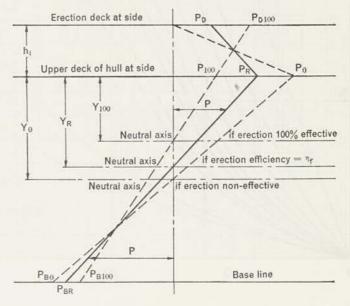


Fig. D 16.4

$$\begin{array}{lll} \mbox{where} & \mbox{P_0} = & \frac{100\mbox{NY}_0}{I_0} & \left(\frac{\mbox{NY}_0}{I_0}\mbox{ British}\right) \\ \\ \mbox{P_{100}} = & \frac{100\mbox{NY}_{100}}{I_{100}} & \left(\frac{\mbox{NY}_{100}}{I_{100}}\mbox{ British}\right) \\ \\ \mbox{P_R} = & \mbox{P_0} - \eta_f \; (\mbox{P_0} - \mbox{P_{100}}) \\ \\ \mbox{P_{BR}} = & \mbox{P_{B0}} - \eta_f \; (\mbox{P_{B0}} - \mbox{P_{B100}}) \\ \\ \mbox{P_{D100}} = & \frac{100\mbox{N} \; (\mbox{Y}_{100} + \mbox{h_1})}{I_{100}} & \left(\frac{\mbox{N} \; (\mbox{Y}_{100} + \mbox{h_1})}{I_{100}} \, \mbox{British}\right) \\ \\ \mbox{P_D} = & \eta_f \; \mbox{P_{D100}} \\ \\ \mbox{N} = & \mbox{Rule} \; \frac{\mbox{I}}{\mbox{y}} \; \mbox{for mild steel, in cm}^3 \; \mbox{(in}^2\mbox{ft), obtained from Section D 3,} \\ \end{array}$$

I₀ = moment of inertia, in cm⁴ (in²ft²), of the hull only about the neutral axis, I₁₀₀ = moment of inertia, in cm⁴ (in²ft²), of hull and all tiers of effective erections about the neutral axis, assuming the erections to be 100 per cent effective.

Openings in erection sides and decks are to be deducted and the calculation carried out at the worst cross section including all effective erections within 0,4L amidships.

Where materials with modulus of elasticity e are used in the erections, the area of this material to be used in the calculation of I_{100}

is the actual area multiplied by E,

Y₀, Y_R, and Y₁₀₀ (see Fig. D 16.4) are to be measured in metres (feet).

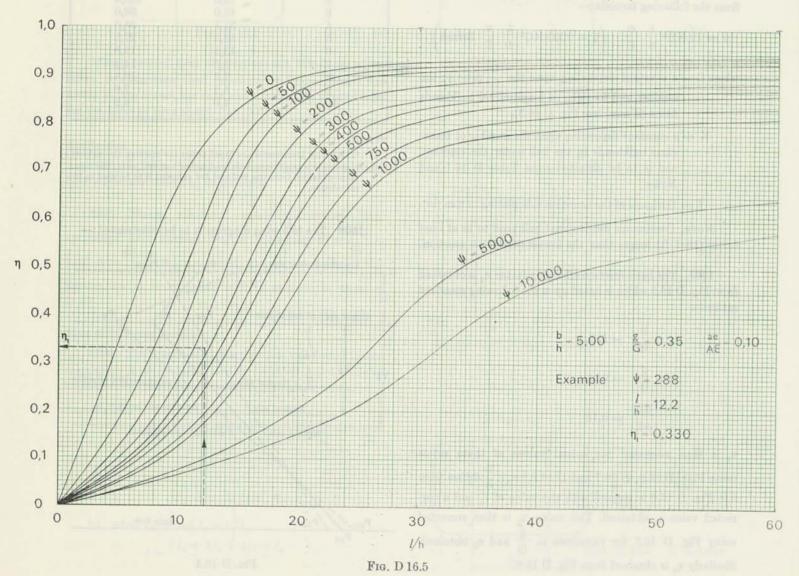


Fig. D 16.5

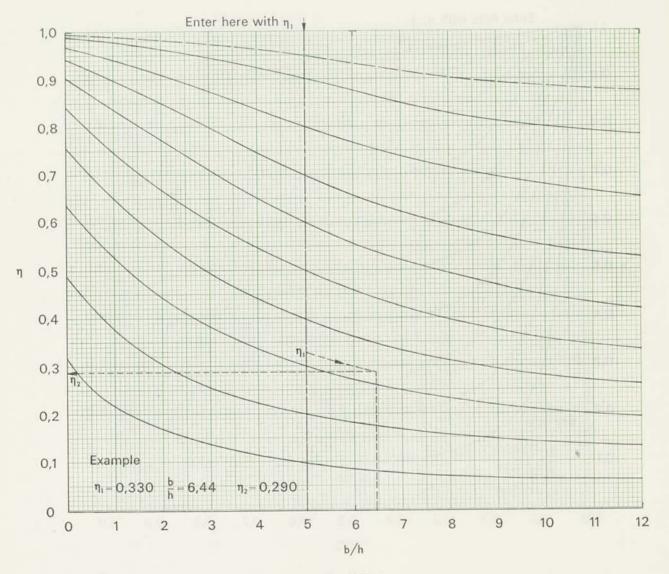


Fig D 16.6

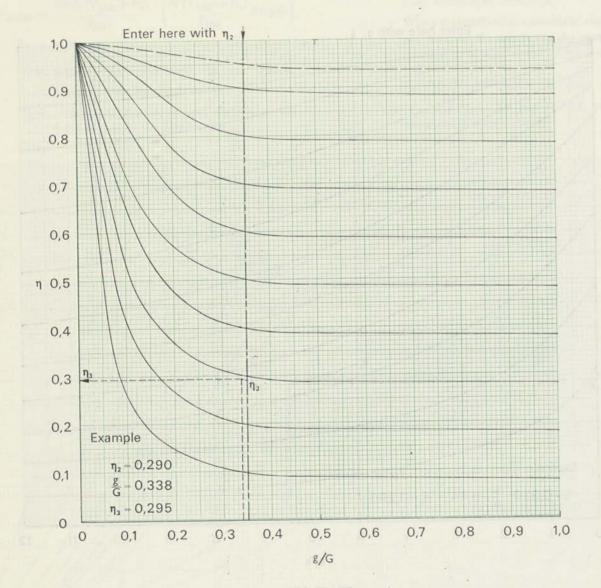


Fig. D 16.7

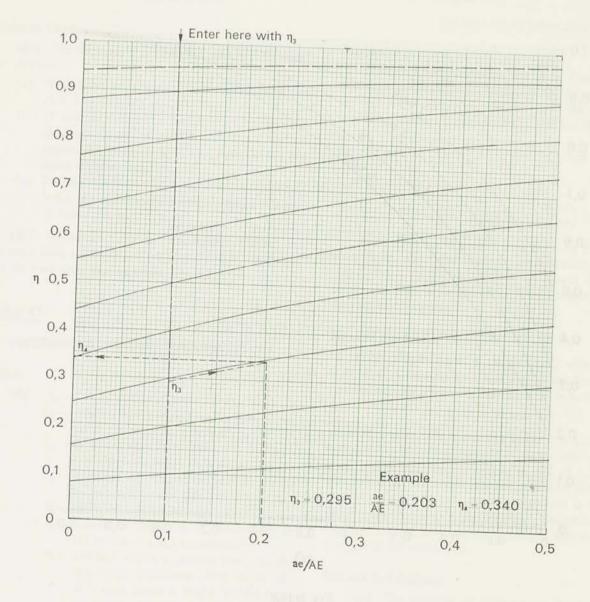


Fig. D 16.8

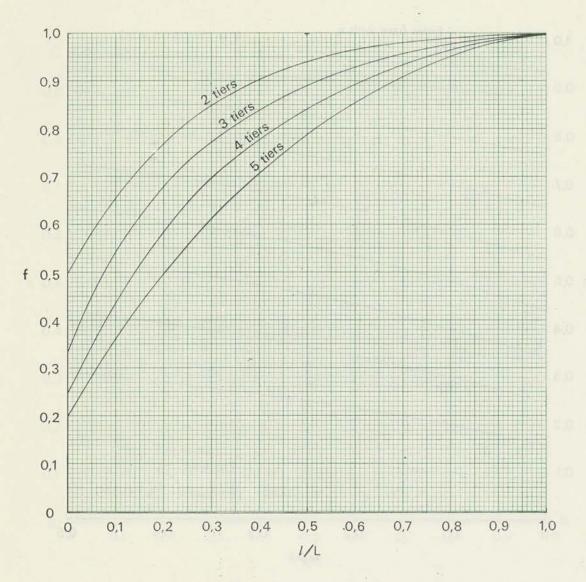


Fig D 16.9

Maximum P Values

1609 In Fig. D 16.4 the ordinate P of the straight lines joining P_D , P_R and P_{BR} at any point must not exceed:—

1.0 for mild steel,

1,5 for aluminium alloy,

1,0 for higher tensile steel, where k is

k as defined in D 65.

Minimum Thickness

1610 The thickness of deck plating is to be determined as follows:—

(a) If erection efficiency factor = 0 then the thickness should be derived from D 1708.

(b) If erection efficiency factor = 1,0 then the thickness should be derived from D 403 for the uppermost erection deck, and from D 412 for lower erection decks.

(c) For intermediate values of erection efficiency factor, the minimum thickness should be obtained by interpolation.

1611 Where erections are transversely framed, the minimum deck thickness will be considered in association with the maximum sagging stress. See D 3.

Section 17

SUPERSTRUCTURES AND DECKHOUSES

Symbols

1701

L = length of ship, in metres (feet).

L₁ = length of ship, in metres (feet), but need not be taken greater than 215 m (705 ft).

 $\mathsf{L}_2=$ length of ship, in metres (feet), but need not be taken greater than 250 m (820 ft).

L₃ = length of ship, in metres (feet), but is not to be taken greater than 134 m (440 ft).

B = moulded breadth, in metres (feet).

b = breadth of deckhouse, in metres (feet), at the bulkhead under consideration.

D = moulded depth, in metres (feet), to the uppermost continuous deck or to the deck next above a height of 1,6d from the base line amidships, whichever is the lesser.

d = moulded draught, in metres (feet).

 $C_b =$ block coefficient and is not to be taken as less than 0.68.

s = spacing of beams or stiffeners, in mm (in).

t = thickness of plating, in mm (in).

$$E_1 = \frac{L - 50}{20 \, (D - d)} + 3.3$$

but need not be taken greater than 5,55.

or in British units:-

$$\mathsf{E_i} = \frac{\mathsf{L} - 164}{100 \, (\mathsf{D} - \mathsf{d})} + 0.65$$

but need not be taken greater than 1.10.

Forecastles

1702 All sea-going ships are to be fitted with forecastles or increased sheer, such that the distance between the summer load waterline and the top of the exposed deck at side (at the fore perpendicular) is not less than:—

$$56 \, \mathsf{L_2} \left(\! 1 - \! \frac{\mathsf{L_2}}{500} \! \right) \left(\! \frac{1,\!36}{\mathsf{C_b} + 0,\!68} \! \right) \, \mathrm{mm}$$

or in British units:-

0,672
$$\mathsf{L_2} \left(1 - \frac{\mathsf{L_2}}{1640}\right) \left(\frac{1 \cdot 36}{\mathsf{C_b} + 0 \cdot 68}\right)$$
 in

Forecastles are to extend from the stem to a point at least 0,07L abaft the forward perpendicular, or if the required bow height is obtained by means of increased sheer, the sheer is to extend for at least 0,15L from the forward perpendicular.

Side and End Plating

1703 The thickness of the fore ends, sides and after ends of all superstructures and deckhouses (except those forming exposed machinery casings) is not to be less than:—

$$t = E_1 R_1 \sqrt{s} mm$$
 (in)

where R_1 is given in Tables D 17.1 and D 17.2; but in no case is a poop, bridge or deckhouse front, on the deck to which D is measured, nor the exposed after end of a deckhouse situated at the after end of this deck, to have a thickness less than 6,5 mm (0·26 in). Plating elsewhere is to have a thickness not less than 5 mm (0·20 in). The sides of bridges 0,15L, or greater, in length are to comply with the requirements of D 501 and D 505.

Side and End Stiffeners

1704 The modulus of stiffeners on the fronts, sides and after ends of all superstructures and deckhouses (except on exposed machinery casings or where frames are required by D 707) is not to be less than:—

$$\frac{I}{v} = \frac{E_1 R_2 s L_1}{600} cm^3 (in^3)$$

where R, is given in Tables D 17.1 and D 17.2.

TABLE D 17.1

Erections on the deck to which D is measured	R ₁	R ₂	
(See 1701).	Metric and British units	Metric units	British units
Fore ends of bridges. Fore ends of poops where no bridge or large mid- ship deckhouse is fitted.	0,072	0,487	1.16
Fore ends of poops where a bridge or large midship deckhouse is fitted.	0,063	0,122	0.29
Fore ends of midship deckhouses. Fore ends of after deckhouses where no bridge or large midship deckhouse is fitted.	0,063 + 0,009b B	$0,122 + \frac{0,365b}{B}$	$0.29 + \frac{0.87b}{B}$
Fore ends of after deckhouses where a bridge or large midship deckhouse is fitted.	$0,053 + \frac{0,01b}{B}$	0,122	0.29
Sides of bridges less than 0,15L in length and of poops.	$ \begin{array}{c} 0,054 + \frac{L_1}{7620} \\ \left(0.054 + \frac{L_1}{25000}\right) \\ \text{British} \end{array} $	Modulus to be D 707 and	
Sides of forecastles but s in 1703 is not to be taken less than 700 mm (27 · 5 in).	$\begin{array}{c} 0.06 + \frac{L_1}{7620} \\ \left(0.06 + \frac{L_1}{25000}\right) \\ \text{British} \end{array}$	Modulus to be D 707 and D	
Sides of deckhouses.	$0,055 + \frac{0,01b}{B}$	0,105	0.25
After ends of bridges, forecastles and midship deckhouses forward of 0,15L from aft perpendicular.	0,052	$0.084 - \frac{L_3}{3190}$	$0.2 - \frac{L_3}{4400}$
After ends of after deckhouses and bridges within 0,05L from aft perpendicular.	0,065	0,210	0.50

^{*} Intermediate values by interpolation.

TABLE D 17.2

Fractions on July about that to which D is	R ₁	R	2
Erections on decks above that to which D is measured (See 1701).	Metric and British units	Metric units	British units
Fronts of second tier erections.	88% of first tier values of R ₁	37% of first tie Minimum 0,055	
Sides and after ends of second tier erections.	88% of first tier	50% of first tie Minimum for sides 0,042	Minimum for
	88% of first tier values of R ₁ All values of R ₁ may be reduced by a further 6% of the first tier	For superstructures, see D 707 an D 709	
Fronts, sides and after ends of third and subse-	may be reduced by a further 6%	37% of second t Minimum for fronts 0,042	
quent tiers.	value for each tier above the second.	For superstructures, see D 707 and D 709	

1705 When an erection exceeds 2,6 m (8.5 ft) in height, the modulus of the stiffeners is to be increased in direct proportion.

Exposed Machinery Casings

1706 Exposed machinery casings situated on the deck to which D is measured (see 1701) are to have plating thicknesses 15 per cent greater than those required for superstructures in the same positions.

Where such casings are situated at the after end of the ship the modulus of the stiffeners is not to be less than:—

$$\frac{I}{y} = \frac{E_1 R_2 s L_1}{600} \text{ cm}^3 \text{ (in}^3)$$

where R, has the following values:-

Forward ends of casings 0,633 (1.51 British) Sides of casings 0,341 (0.81 British)

After ends of casings 0,487 (1.16 British)

When the casings on this deck are situated amidships, the modulus of the stiffeners is to be not less than 50 per cent in excess of that required for superstructures in the same position.

1707 Exposed machinery casings forming part of second or higher tiers of superstructures or deckhouses, are to have plating thicknesses 10 per cent in excess of those required for deckhouses in the same position and stiffeners with a modulus 20 per cent in excess of that required for deckhouses in the same position.

Deck Plating

1708 The thickness of deck plating is to be in accorddance with the requirements of D 16 where applicable but is not to be less than:—

$$t = \left(\frac{\mathsf{N_1}\;\mathsf{L_3}}{1000} + \mathsf{N_2}\right)\mathsf{E_2}\sqrt{\frac{s}{\mathsf{N_3}}}\;\mathrm{mm}\;\mathrm{(in)}$$

where N₁, N₂, N₃ and E₂ are given in Table D 17.3.

1709 When decks are fitted with approved sheathing, the thicknesses derived from 1708 may be reduced in accordance with D 420.

The thicknesses, after reduction for sheathing, may be reduced by a further 10 per cent within the line of openings on exposed decks other than forecastles. Inside deckhouses the thickness may be reduced by a further 10 per cent.

1710 Transverse deck beams on the lowest tier of deckhouses less than 0,15 L in length, and on the second tier of erections when the lowest tier is 0,15 L or more in length, are to have a modulus not less than:—

$$\frac{\mathrm{I}}{\mathrm{y}} = \frac{l \, \mathrm{s}}{1420} \, (2.5l \, + 0.115 \, \mathrm{L_1} - 4.5) \, \mathrm{cm}^3$$

$$\left(\frac{I}{y} = \frac{l \ s}{3000} (0.76l + 0.035L_1 - 4.5) \text{ in}^3\right)$$

where l = span of beam, in metres (feet), but is not to be taken as less than 3,05 m (10 ft).

For short bridges, poops and forecastles, see D 806.

TABLE D 17.3

	should be like orability	Metric units	British units
	forecastles erections other than forecastles	17,5 12,5	0·21 0·15
N ₂	tops of erections on the deck to which D has been measured (See 1701) tops of second tier erections tops of third and higher tiers of erections	5,5 5,0 4,5	0·216 0·197 0·177
N ₃ forward of 0,2L from forward perpendicular		frame spacing in mm (inches as required by D 705 and D 706.	
N_3	elsewhere	760	30
E,	$a = 0.895 + {0.064 + 0.0021L \choose D - d}$ $a = 0.895 + {0.21 + 0.0021L \choose D - d}$ British		be taken less or more than

If there is no superimposed erection on the deck being supported, the modulus derived above may be reduced by 20 per cent.

1711 The beams of the tier next above that specified in 1710 are to have a modulus not less than 80 per cent of that required by 1710. The beams of the second and subsequent tier above that specified in 1710 are to have a modulus not less than 60 per cent of that required by 1710.

Strengthening at Ends and Sides of Erections

1712 Web frames or partial bulkheads are to be fitted within bridges and poops which have large deckhouses or other erections above.

Web frames or equivalent strengthening are also to be arranged to support the sides and ends of large deckhouses. These web frames should be spaced about 9 m (29.5 ft) apart and are to be arranged, where practicable, in line with watertight bulkheads below. Webs are also to be arranged in way of large openings, boat davits and other points of high loading.

1713 Arrangements are to be made to minimize the effect of discontinuities in erections. All openings cut in the sides should be substantially framed and have well rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings. House tops are to be strengthened in way of davits.

1714 Attention is to be given to the structure at the corners and ends of erections.

Adequate support under the ends is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams. Deckhouses should be connected to the deck by tee bars, or similar arrangement, at the corners of the houses and in way of supporting structures.

1715 The thickness of the upper deck sheerstrake is to be increased by 50 per cent and the deck stringer plate by 25 per cent at the ends of bridges having a length of 0,15L or greater. Similar strengthening is to be fitted at the ends of poops or forecastles within 0,5L amidships.

At the ends of bridges shorter in length than 0,15L, the increases in thickness are to be 30 per cent and 10 per cent respectively.

The side plating of bridges having a length of 0,15L or greater, is to be increased in thickness by 25 per cent at the ends of the structure and is to be tapered into the upper deck sheerstrake. This plating is to be efficiently stiffened at the upper edge and supported by web plates not more than 1,5 m (5 ft) from the end bulkhead.

End Connections of Deckhouse Stiffeners

1716 The end connections of stiffeners are to be as given in Table D 17.4,

TABLE D 17.4

	Position	Attachment at top and bottom
1.	Front stiffeners of lower tiers and on upper tiers when L is 160 m (525 ft) or greater.	See Table D 32.1, Note 6.
2.	Front stiffeners on upper tiers when L is less than 160 m (525 ft).	Unattached.
3.	Side stiffeners on lower tiers where two or more tiers are fitted.	Bracketed, unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all round.
4.	Side stiffeners if only one tier is fitted and aft end stiffeners of after deckhouses on deck to which D is measured. (See 1701).	See Table D 32.1, Note 6.
5.	Side stiffeners on upper tiers when L is 160 m (525 ft) or greater.	See Table D 32.1, Note 6.
6.	Side stiffeners on upper tiers when L is less than 160 m (525 ft).	Unattached.
7.	Aft end stiffeners except as covered by 4 above.	Unattached.

End Connections of Exposed Machinery Casing Stiffeners

1717 The end connections of stiffeners are to be as given in Table D 17.5.

Aluminium Deckhouses

1718 When an aluminium alloy complying with P12 is used in the construction of deckhouses, the scantlings of these erections are to be increased (relative to those required for steel construction) by the percentages given in Table D 17.6.

The thickness of aluminium alloy stiffening members is not to be less than:—

$$t = 2.5 + 0.022 h \text{ mm}$$
 $(t = 0.10 + 0.022 h \text{ in})$ (1)

where h = depth of the section, in mm (in), but need not exceed 330 mm (13 in).

The minimum moment of inertia of aluminium alloy stiffening members is not to be less than:—

$$I = 5.25 \frac{I}{y} l \text{ cm}^4 \quad \left(I = 0.63 \frac{I}{y} l \text{ in}^4\right)$$
 (2)

where l is the span of the member, in metres (feet), and $\frac{1}{y}$ is the section modulus of the stiffener and attached plating.

1719 Where aluminium erections are arranged above a steel hull, details of the arrangements in way of the bimetallic connection are to be submitted.

TABLE D 17.5

	Position	Attachment at top and bottom
1.	Front stiffeners on amidship casings and all stiffeners on aft end casings which are situated on the deck to which D is measured. See 1701.	Bracketed.
2.	All other stiffeners on casings.	6,5 cm ² (1·0 in ²) of weld.

TABLE D 17.6

Item	Percentage Increase	
Fronts, sides, after ends and unsheathed deck plating.	20	
Decks sheathed in accordance with D 420.	. 10	
Decks sheathed with wood and on which the plating is fixed to the wood sheathing at the centre of each beam space.	Nil	
Stiffeners and beams	70	
Scantlings of small isolated houses.	Nil	

Cross-references

1720 For the effect of erections on longitudinal strength, see D 16.

For superstructure side frames, deck longitudinals and beams, see D 7, D 6 and D 8 respectively.

For connections to sheerstrake, see D 510.

For aluminium deckhouses, see also F 812.

Section 18

WATERTIGHT BULKHEADS

Symbols

1801

- a = height, in metres (feet), of bracket or end stool or lowest strake of plating.
- e = effective length, in metres (feet), of bracket or end stool, as given in Tables D 18.2 and D 18.3.
- h, h_o = vertical distance, in metres (feet), from the middle of span l, S, respectively, to a point 0.91 m (3 ft) above the bulkhead deck at side.

 $l = S - e_1 - e_2$

- = effective span, in metres (feet), of stiffener or corrugation, (see Figs. D 18.1 and D 18.2).
- S = overall height, in metres (feet), of bulkhead between support points (including brackets or end stools if fitted).
- $\gamma = 1.4$ for double plate bulkheads and welded stiffeners other than flat bars,
 - 1,6 for flat bar stiffeners and swedges,
 - 1,1 for symmetrical corrugations.

- ω = end constraint coefficient relating to the ends of the effective span l. Values of ω lie between 0 and 1.
- L_1 = length of ship, in metres (feet), but need not be taken greater than 215 m (705 ft).

Number and Disposition of Transverse Bulkheads

- 1802 All ships are to have a collision bulkhead situated not less than $0.05L_1$ nor more than 0.075L from the fore end of the load waterline, an after peak bulkhead enclosing the stern tubes in a watertight compartment and a bulkhead at each end of the machinery space.
- 1803 Additional watertight bulkheads are to be fitted so that the total number of bulkheads is in accordance with Table D 18.1.
- 1804 The bulkheads in the holds should be spaced at reasonably uniform intervals. Where this is departed from and the length of a hold is unusually great, the transverse strength of the ship is to be maintained.
- 1805 The Committee will be prepared to consider proposals from owners to dispense with one or more of these bulkheads if they interfere with the requirements of a special trade, subject to suitable structural compensation.

Height of Bulkheads

- 1806 The collision bulkhead is to extend to the uppermost continuous deck.
- 1807 The after peak bulkhead may terminate at the first deck above the load waterline, provided this deck is made waterlight to the stern or to a waterlight transom floor.

TABLE D 18.1

Length L				Total number of bulkheads			
Ab	Above Not		Above Not exceeding		Machinery amidships	Machinery aft*	
Metres	Feet	Metres	Feet				
90	295.0	105	344.5	5	5		
105	344.5	115	377.3	6	5		
115	377 - 3	125	410-1	6	6		
125	410.1	145	475.7	7	6		
145	475 - 7	165	541.3	8	7		
165	541.3	190	623 - 4	9	8		
190	623 · 4			To be considered	ed individually.		

*After peak bulkhead forming the after boundary of the machinery space.

1808 The remaining bulkheads are to extend to the uppermost continuous deck except where the draught is not greater than that permitted with a superstructure extending for the full length of the ship above the second deck, when the bulkheads may terminate at that deck provided it lies above the load waterline.

In passenger ships of restricted draught, the height of the bulkhead will be specially considered.

Bulkhead Plating

1809 The thickness of plating of watertight bulkheads which do not form the boundaries of tanks is not to be less than:—

$$t = 0.004 \text{ s} \sqrt{h_1 \text{ mm}} \quad (t = 0.0022 \text{ s} \sqrt{h_1 \text{ in}})$$

unless $\frac{1000S_1}{S}$ $\left(\frac{12S_1}{S}$ British $\right)$ is less than 4, when the thickness obtained from the above formula is to be multiplied by the factor $1,1-\frac{S}{2500S_1}$ $\left(1\cdot1-\frac{S}{30S_1}\right)$ British

where S = (i) stiffener spacing, in mm (in), on plane or double plate bulkheads,

- (ii) breadth, in mm (in), of flange or web, whichever is the greater, for corrugated bulkheads,
- (iii) breadth of flat plating, in mm (in), for swedged bulkheads,
- h₁ = vertical distance, in metres (feet), from a point one third of the height of the plate above its lower edge, to a point 0,91 m (3 ft), above the bulkhead deck at side,
- S₁ = overall length of stiffener between support points, in metres (feet).

The thickness of collision bulkheads not forming the boundaries of tanks is to be 12 per cent greater than the thickness derived from the formula above.

The minimum thickness of bulkhead plating is to be 5,5 mm (0·22 in). Where the class notation includes a reference to ore cargoes the minimum thickness of the hold bulkheads is to be 10 mm (0·40 in).

Bulkhead Stiffeners

1810 The scantlings of stiffeners of watertight bulkheads not forming boundaries of tanks, are to be determined from 1814 for rolled or built stiffeners and swedges and from 1815 for symmetrical corrugations and double plate bulkheads.

The section modulus of stiffeners of collision bulkheads not forming the boundaries of tanks is to be 25 per cent greater than that required for watertight bulkheads.

1811 Where bulkhead stiffeners are cut in way of watertight doors in the lower part of a bulkhead, the opening is to be suitably framed and reinforced.

Where stiffeners are not cut but the spacing between the stiffeners is increased on account of watertight doors, as in 'tween deck bulkheads, the stiffeners at the sides of the doorways are to be increased in depth and strength so that the efficiency is at least equal to that of the unpierced bulkhead, without taking the stiffness of the door frame into consideration.

1812 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

1813 The section modulus of swedges is to be calculated in association with 610 mm (24 in) or the breadth of flat plating, whichever is the lesser.

TABLE D 18.2

ROLLED OR BUILT STIFFENERS AND SWEDGES

End Connection (see Fig. D 18.1)				ω	е
End of stiffener unattached or attached to plating only			(1)	0	0
Member in line at deck or at Rule horizontal girder	Adjacent member B of smaller section		(2)	$\frac{4.5}{M_1} \left(\frac{I}{y} \right)_B \text{ or } 1^*$	0
	Adjacent member B of same or larger section		(3)	1	0
Bracketless connection	Member A within length S		(4)	1	dA
to longitudinal member	Member A out	side length S	(5)	-1	0
Bracketed	To transverse member	Bracket extends to floor	(6)	1	β a or 0,1S*
Bracketed	Otherwise		(7)	1	0
	To longitudin	al member	(8)	1	β a or 0,1S*

where $\beta=1$ for brackets with face bars directly connected to stiffener face bars, 0,7 for flanged brackets, 0,5 for unflanged brackets,

d_A = depth, in metres (feet), of supporting member A (see Fig. D 18.1),

 $\left(\frac{I}{y}\right)_{B}$ = section modulus, in cm³ (in³), of supporting member B,

$$M_{1} = \frac{h s \ell^{2}}{71} \quad \left(\frac{h s \ell^{2}}{1620} \text{ British }\right)$$

*Where two values of ω or e are given in the Table, the smaller is to be used.

Rolled or Built Stiffeners and Swedges

1814 The section modulus of rolled or built stiffeners and swedges, calculated at the middle of span *l* on water-tight bulkheads not forming boundaries of tanks is not to be less than:—

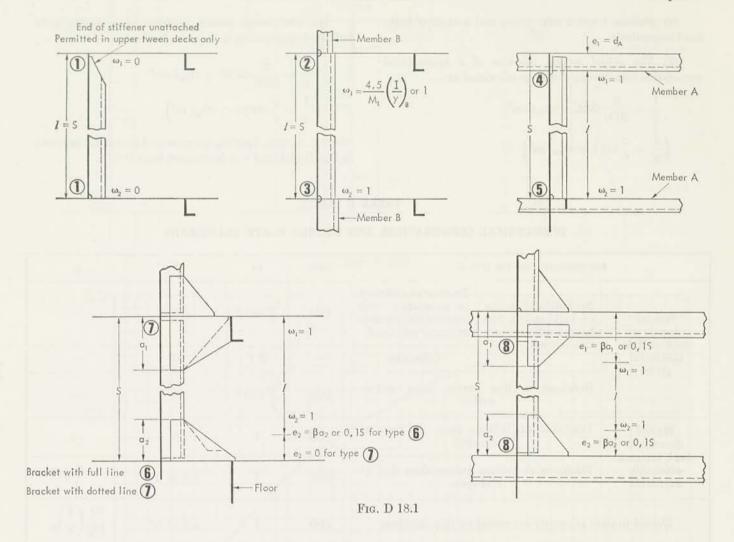
$$\frac{I}{\text{y}} = \frac{\text{hs}\, \text{l}^2}{71\, \gamma\, (\omega_1 + \omega_2 + 2)} \,\, \text{cm}^3 \, \left(\frac{\text{hs}\, \text{l}^2}{1620\, \gamma\, (\omega_1 + \omega_2 + 2)} \, \text{in}^3 \right)$$

where S = spacing of stiffeners, in mm (in).

The ratio of the web depth to the web thickness is not to exceed 60 for stiffeners with flanges or face plates and 18 for flat bars.

Notes.

(1) Various types of end connection are listed in Table D 18.2 and illustrated in Fig. D 18.1 for the corresponding type number, together with appropriate values of end constraint ω and, where applicable, effective bracket length e. Suffixes I and 2 refer to top and bottom of stiffener respectively.



- (2) When a bulkhead consists of several spans of vertical stiffeners supported by 'tween decks or horizontal girders, it is recommended that the top span should be calculated first and then the other spans considered from the top span downwards.
- (3) For convenience of definition, Table D 18.2 implies vertical stiffening on transverse bulkheads. The Rules also apply to horizontal stiffening and longitudinal bulkheads, providing due regard is paid to the appropriate directions of end supporting members.
- (4) Bracketless connections type (4) may be made by welding the stiffening members "back to back" with as large an overlap as possible, or with the flanges on the same side, provided the web at the corner of the connection is suitably strengthened with a doubling plate or a diagonal stiffener.

Symmetrical Corrugations and Double Plate Bulkheads

1815 The section modulus of symmetrical corrugations and double plate bulkhead primary members, calculated at the middle of span l on watertight bulkheads not forming boundaries of tanks, is not to be less than:—

$$\frac{I}{y} = \frac{h p l^2}{71 \gamma (\omega_1 + \omega_2 + 2)} cm^3$$

$$\frac{I}{y} = \frac{h p l^2}{1620 \gamma (\omega_1 + \omega_2 + 2)} in^3$$

where p is the spacing of corrugations or vertical webs of double plate bulkheads (see Fig. D 18.4).

NOTES.

(1) Various types of end connection are listed in Table D 18.3 and illustrated in Fig. D 18.2 for the corresponding type number, together with appropriate values of end constraint ω and, where applicable, effective stool length e.

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- (2) Suffixes 1 and 2 refer to top and bottom of bulk-head respectively.
- (3) The actual section modulus of a symmetrical corrugation over spacing p may be calculated as:

$$\frac{I}{y} = \frac{d}{6000} \left(3bt + ct_{w} \right) cm^{3}$$

$$\left(\frac{1}{y} = \frac{d}{6} \left(3bt + ct_{w}\right) in^{3}\right)$$

(4) The actual section modulus of a double plate bulkhead over spacing p may be calculated as:—

$$\frac{I}{y} = \frac{d}{6000} \left(6 \text{kpt} + dt_{\text{w}} \right) \text{cm}^3$$

$$\left(\frac{1}{y} = \frac{d}{6} (6kpt + dt_w) in^3\right)$$

where b, c, d, p, t and $t_{\rm W}$ are measured in mm (in) as shown in Fig. D 18.4, and k is determined from D 5304.

TABLE D 18.3

SYMMETRICAL CORRUGATIONS AND DOUBLE PLATE BULKHEADS

F	End Connection (see Fig. D	18.2)	Туре	ω	е	μ
Welded or bulkhead in having different tion outline		Transverse stiffeners in association with longitudinal brackets at top of bulkhead	. (11)	t _e or 1*	0	
horizontal girder	tion outline	Otherwise		0,1	0	
Bulkhead in line	naving same section	(13)	t _B or 1*	0	=	
directly to mid-		m same as that at span	(14)	1	0	<u> </u>
tank top and efficiently supported		greater than that at span	(15)	1	αS or a*	te
Welded to sto	ool efficiently supported	by ship structure	(16)	1	αS or a*	$\frac{10}{M_2} \left(\frac{I}{y} \right)_{S}$

where $t, t_e = \text{thickness}$, in mm (in), of flange plating of corrugation or double plate bulkhead, at

mid-span or end respectively,

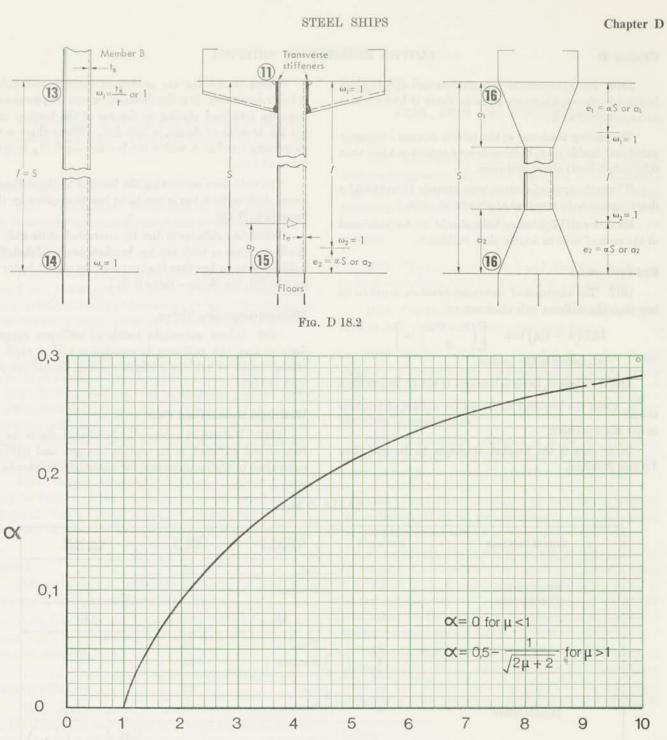
t_B = thickness, in mm (in), of flange plating of member B,

 $\alpha = \text{coefficient given in Fig. D 18.3,}$

 $\left(\frac{I}{y}\right)_S = \begin{array}{l} \text{modulus, in cm}^3 \ (\text{in}^3), \ \text{of horizontal section of} \\ \text{stool adjacent to deck or tank top over} \\ \text{breadth p. All material continuous from top} \\ \text{to bottom of the stool may be included in the} \\ \text{calculation,} \end{array}$

$$\mathsf{M_2} = \frac{\mathsf{h_0} \, \mathsf{p} \, \mathsf{S^2}}{71} \quad \left(\mathsf{M_2} = \frac{\mathsf{h_0} \, \mathsf{p} \, \mathsf{S^2}}{1620} \; \operatorname{British} \; \right)$$

*Where two values of ω or e are given in the Table, the smaller is to be used.



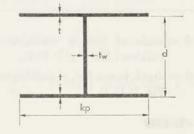


Fig. D 18.4

Fig. D 18.3

1816 For symmetrical corrugations and double plate bulkheads, the requirements given in Table D 18.4 are also to be complied with.

The plating thickness at the middle of span / of corrugated and double plate bulkheads is to extend not less than 0.2/ metres (feet) above mid-span.

Where the span of corrugations exceeds 15 m (49 ft) a diaphragm is to be arranged at about mid-span.

Manholes and lightening holes should not be positioned at the ends of webs in double plate bulkheads.

End Connections

1817 The thickness of unflanged brackets is not to be less than the stiffener web thickness or

16,7
$$(a - d_A)$$
 mm $\left[\left(\frac{a - d_A}{5}\right)$ in $\right]$

whichever is the greater.

The thickness of flanged brackets is not to be less than b times the required thickness for unflanged brackets in the same position.

In no case is the bracket thickness to be less than 7.5 mm (0.30 in).

Where a and d_A are as defined in 1801 and Table D 18.2 respectively, b is the distance, in mm (in), measured from the bulkhead plating to the toe of the bracket and f is the breadth of flange, in mm (in). Where there is no supporting member A within the bracket depth d_A is to be taken as zero.

The weld area connecting the bracket to the stiffener, beam, deck or tank top is not to be less than given by the formulæ in D 733.

Where the stiffener is directly connected at its ends to the deck, beam or tank top, i.e. brackets are not fitted, the weld is not to be less than that required for a weld factor of 0,44 (0.63). See Notes—Table D 32.1.

Stiffeners supporting Girders

1818 Where watertight bulkhead stiffeners support deck girders, the stiffeners, in association with a width of plating equal to half the stiffener spacing, should comply with D 1402.

Watertight Recesses and Flats

1819 Watertight recesses in bulkheads are to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

TABLE D 18.4

Type of Bulkhead	Parameter	Position in Bulkhead	Not to exceed	Not to be less than
	b	∫ Top	85	
Symmetrical Corrugation	t	Bottom	70	
Corragation	θ	All	-X	40°
	S	∫ Top	. 75	
	t	Bottom	65	
	d	∫ Top	85	
Double plate	tw	Bottom	75	
		Top		$\frac{0.12 \frac{\text{I}}{\text{y}} \text{ cm}^2}{l} \left(\frac{\frac{\text{I}}{\text{y}}}{l} \text{ in} \frac{0.18 \frac{\text{I}}{\text{y}}}{l} \text{ cm}^2 \left(\frac{1.5 \frac{\text{I}}{\text{y}}}{l} \text{ in} \frac{1.5 \frac{\text{I}}{\text{y}}}{l} \right) \right)$
	.Aw	Bottom	- 1 - 1 - 1 - 1 - 2 - 2 - 2 - 2 - 2 - 2	$\frac{0.18\frac{1}{y}}{l} \text{ cm}^2 \left(\frac{1.5\frac{1}{y}}{l} \text{ i}\right)$

where θ = angle of web of corrugation to plane of bulkhead (see Fig. D 18.4),

> d = depth, in mm (in), of double plate bulkhead (see Fig. D 18.4),

S = spacing, in mm (in), of vertical stiffeners of double plate bulkhead,

A_w = section area, in cm² (in²), of webs of double plate bulkhead.

1820 Horizontal plating is to be 1 mm (0.04 in) thicker than required by 1809 at a corresponding level.

The thickness of plating and scantlings of beams or longitudinals are not to be less than required by D 4, D 8 or D 6.

Chain Lockers

1821 Chain lockers fitted abaft the collision bulkhead are to be watertight and the space is to be efficiently drained.

Watertight Doors

1822 Watertight doors are to be efficiently constructed and fitted, and should be capable of being operated when the ship is listed up to 15 degrees either way. They are to be operated under working conditions and hose tested in place. (See 1826).

1823 Watertight doors of the sliding type are to be capable of being operated by efficient hand operated gear, both at the door itself and from an accessible position above the bulkhead deck. Means shall be provided at the remote operating position to indicate whether the door is open or closed. The lead of shafting is to be as direct as possible and the screw is to work in a gunmetal nut. (See also D 2001).

1824 Hinged watertight doors of approved pattern may be fitted in 'tween decks in approved positions. The hinges of these doors are to be fitted with gunmetal pins or gunmetal bushes.

Testing

1825 Watertight bulkheads including recesses and flats are to be hose tested on completion.

Peak bulkheads not forming boundaries of tanks are to be tested by filling the peaks with water to the level of the load waterline.

Passenger Ships

1826 In passenger ships the number and construction of the watertight bulkheads and watertight doors will be specially considered. Each watertight door shall be tested by water pressure to a head up to the bulkhead deck. The test may be carried out either before or after the door is fitted. (See F 801 and F 805).

Cross-references

1827 For peak and deep tanks, see D 19.

For watertight tunnels, see D 20.

For machinery casings in 'tween decks, see D 2109.

Section 19

PEAK, DEEP AND TOPSIDE TANKS

General

1901 This Section gives the required scantlings for tanks carrying water, oil fuel for ship's use, or oil (including vegetable oil) and other liquids carried as cargo. When boundary bulkheads form part of the watertight sub-division of the ship, the requirements of D 18 are also to be satisfied.

1902 The scantlings of fore and after peak tanks are to be in accordance with D 54 and D 55 respectively.

1903 The flash point of oil fuel, or oil carried as cargo, is to be 60°C (140°F) or above (closed cup test).

1904 Where tanks are intended for other liquid cargoes of a special nature the scantlings and arrangements will be considered in relation to the nature of the cargo.

Structural Arrangements

1905 A centreline bulkhead is to be fitted in deep tanks which extend from side to side of the ship and are intended for the carriage of oil fuel for the ship's use.

1906 Centreline bulkheads may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads.

If perforated, the modulus of the stiffeners may be 50 per cent of that required for boundary bulkheads, using h measured to the crown of the tank. The stiffeners are to be bracketed at top and bottom. The area of perforation is to be not less than 5 per cent nor more than 10 per cent of the total area of the bulkhead.

When brackets from horizontal girders on the boundary bulkheads abut on the centreline bulkhead a light intercostal stringer is to be fitted at that level for the full length of the tank, or equivalent arrangements are to be provided.

Plating

1907 The thickness of plating forming the boundaries of tanks is not to be less than:—

$$\begin{split} t &= 0{,}004 \text{ s} \sqrt{\frac{\rho \text{ h}_2}{1{,}025}} + 2{,}5 \text{ mm} \\ \left(t &= 0{\cdot}0022 \text{ s} \sqrt{\frac{\rho \text{ h}_2}{1{\cdot}025}} + 0{\cdot}1 \text{ in} \right) \end{split}$$

unless
$$\frac{1000 \, S_1}{s} \, \left(\frac{12 \, S_1}{s} \, \text{British}\right)$$
 is less than 4, when the

thickness obtained from the above formula is to be multiplied by the factor:—

$$1.1 - \frac{\text{S}}{2500 \, \text{S}_1} \, \left(1 \cdot 1 - \frac{\text{S}}{30 \, \text{S}_1} \, \text{British} \right)$$

where S = stiffener spacing, in mm (in), on plane or double plate bulkheads, or breadth, in mm (in), of flange or web, whichever is the greater, for corrugated bulkheads, or

breadth of flat plating, in mm (in), for swedged bulkheads,

 $\rho=$ specific gravity of the liquid to be carried and is not to be taken as less than 1,025,

h₂ = vertical distance, in metres (feet), from a point one-third of the height of the plate above its lower edge to the top of the tank or half the distance to the top of the overflow, whichever is the greater,

S, = overall length of stiffener between support points, in metres (feet).

The minimum thickness of plating is to be 7,5 mm (0.30 in).

Rolled or Built Stiffeners and Swedges

1908 The section modulus and inertia of rolled or built stiffeners and swedges, calculated at the middle of span *l* on bulkheads forming tank boundaries, is not to be less than:—

$$\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{h}\,\mathrm{s}\,l^2}{21.5\,\gamma\,(\omega_1 + \omega_2 + 2)} \,\,\mathrm{cm}^3$$

$$\left(\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{h}\,\mathrm{s}\,l^2}{490\,\gamma\,(\omega_1 + \omega_2 + 2)} \,\,\mathrm{in}^3\right)$$
and $1 = 2.3\,\frac{\mathrm{I}}{\mathrm{y}}\,l\,\,\mathrm{cm}^4$ $\left(\mathrm{I} = 0.276\,\frac{\mathrm{I}}{\mathrm{y}}\,l\,\,\mathrm{in}^4\right)$

The symbols used are as defined in D 1801, D 1814 and the values of ω and e are to be derived from Table D 18.2 except that:—

h, h_o = vertical distance, in metres (feet), from the middle of span l, or S respectively, to the top of the tank or half the distance, in metres (feet), from the middle of the span to the top of the overflow, whichever is the greater.

Where the specific gravity, ρ , of the liquid to be carried exceeds 1,025, the values of h and h₀ are

to be multiplied by the factor $\frac{\rho}{1,025}$

$$M_1 = \frac{h s \ell^2}{21,5}$$
 $\left(M_1 = \frac{h s \ell^2}{490} \quad British\right)$

The ratio of the web depth to the web thickness is not to exceed 60 for stiffeners with flanges or face plates and 18 for flat bars.

1909 For swedges, the section modulus is to be calculated in association with 610 mm (24 in) of attached plating or the breadth of flat plating, whichever is the lesser.

End Connections

1910 Stiffener end connections are to be as required by D 1817.

Note. End connections of type (1) (see Fig. D 18.1) are not permitted at tank boundaries.

Symmetrical Corrugations and Double Plate Bulkheads

1911 The section modulus of symmetrical corrugations and double plate bulkhead primary members, calculated at the middle of span l on bulkheads forming tank boundaries, is not to be less than:—

$$\frac{1}{\text{y}} = \frac{\text{h p } \text{l}^2}{21,5\,\gamma\,(\omega_1+\omega_2+2)}\,\text{cm}^3$$

$$\left(\frac{\text{I}}{\text{y}} = \frac{\text{h p } \mathit{l}^2}{490\,\gamma\,(\omega_1 + \omega_2 + 2)}\right) \text{ in}^3$$

The symbols used are as defined in D 1801 and D 1815 and the values of ω and e are to be derived from Table D 18.3 except that h and h_o are as defined in 1908 and

$$M_2 = \frac{h_0 p S^2}{21,5} \qquad \left(M_2 = \frac{h_0 p S^2}{490} \quad British\right)$$

The depth d of symmetrical corrugations and double plate bulkheads is not to be less than:—

$$d = 39l \text{ mm} (0.47l \text{ in})$$

1912 The section modulus of symmetrical corrugations and double plate bulkheads may be calculated as described in D 1815, Notes 3 and 4.

1913 For symmetrical corrugations and double plate bulkheads forming tank boundaries, the requirements of Table D 19.1 are also to be complied with.

The plating thickness at the middle of span l of corrugated and double plate bulkheads is to extend not less than 0,2l metres (feet) above mid-span.

Where the span of corrugations exceeds 15 m (49 ft) a diaphragm is to be arranged at about mid-span.

Manholes and lightening holes should not be positioned at the ends of webs in double plate bulkheads, unless suitable reinforcement is provided.

Girders

1914 The section modulus and moment of inertia of girders, when fitted, are not to be less than:—

$$\frac{I}{y} = 12 \, h \, b \, S_{G}^{2} \, cm^{3} \qquad \left(\frac{1}{y} = \frac{h \, b \, S_{G}^{2}}{158} \, in^{3} \right) \ (1)$$

and
$$I = 2.5 \text{ S}_{\text{G}} \frac{I}{y} \text{ cm}^4$$
 $\left(I = 0.3 \text{ S}_{\text{G}} \frac{I}{y} \text{ in}^4\right)$ (2)

where h = vertical distance, in metres (feet), from the mid-point of length to the top of the tank or half the distance, in metres (feet), from the mid-point of length to the top of the overflow, whichever is the greater. For girders supporting side frames, h is in no case to be taken as less than the distance from the girder to the upper deck at side or to a line 1,4d above the keel, whichever is the lesser.

b = distance, in metres (feet), between the centres of the two adjacent spans of stiffeners or frames supported by the girder,

d = moulded draught, in metres (feet),

S_G = span of girder, in metres (feet), measured between span points as shown in Fig. D 46.1.

Where the specific gravity, ρ , of the liquid to be carried exceeds 1,025 the value of $\frac{I}{y}$ is to be multiplied by the factor:—

1915 If girders are fitted, they are to form a continuous line of support on bulkheads and ship's side. The thickness of the girder web plate is not to be less than:—

$$t = 9 + 0.008 \left(\frac{d_W}{50}\right)^2 mm$$

$$\left(t = 0.35 + 0.2 \left(\frac{d_W}{50}\right)^2 in\right)$$

where dw = depth of web, in mm (in).

TABLE D 19.1

Type of Bulkhead	Parameter	Position in Bulkhead	Not to exceed	Not to be less than
Symmetrical Corrugations	b t	$\begin{cases} \text{Top} \\ \text{Bottom} \end{cases}$	} 70	
Corrugations	θ	All		40°
	s t	$\begin{cases} \text{Top} \\ \text{Bottom} \end{cases}$	75 65	
Double plate	d t _w	{ Top Bottom	85 75	
	A	Top		$\frac{0.07\frac{1}{\text{V}}\text{cm}^2\left(0.58\frac{1}{\text{y}}\text{ir}\right)}{l}$
	Aw	Bottom		$\frac{0.1 \frac{1}{\text{y}} \text{ cm}^2}{t} \left(\frac{0.83 \frac{1}{\text{y}} \text{ in}}{t} \right)$

where θ = angle of web of corrugation to plane of bulkhead (see Fig. D 18.4),

d = depth, in mm (in), of double plate bulkhead,

S = spacing, in mm (in), of vertical stiffeners of double plate bulkhead,

 $A_W = \text{section area, in cm}^2$ (in²), of webs of double plate bulkhead.

They are to be connected at their ends by flanged brackets having the same thickness as the web plate of the thicker girder and a length of arm, measured from the point of the bracket to the edge of the girder, equal to the width of the wider girder. If the bracket terminates on a bulkhead the length of the arms is to be equal to the width of the girder. The ends of the brackets are to be adequately supported.

1916 The girders are to be supported by tripping brackets at the toes of the end brackets and elsewhere at every third stiffener or frame. Stiffeners or frames intermediate between these brackets are to be effectively connected to the girders.

Topside Tanks

1917 The thickness of the sloping bulkhead plating is to be as required by 1907 but h is not to be taken as less than that at the half-width of the tank.

In no case is the thickness to be less than required by D 412 for second deck—outside line of openings.

When the vertical strake of plating under the hatch coaming is greater than 20,5 mm (0.8 in) but does not exceed 25,5 mm (1.0 in) in thickness, it is to be of Grade B quality steel within 0,4L amidships.

When the thickness exceeds 25,5 mm ($1 \cdot 0$ in), Grade D steel is to be used.

See also D 6519 for higher tensile steel.

1918 Particular attention is to be paid to the structural arrangements within topside tanks.

A transverse should normally be arranged in line with the ends of the main cargo hatchways and in ships exceeding 215 m (705 ft) in length, a fore and aft diaphragm extending vertically from the deck to the sloping plating of the topside tank, may be required at about the half-width of the tank.

Decks

1919 The thickness of plating of a deck forming the crown of a tank is to be 1,0 mm (0.04 in) greater than that which would be required by 1907, but is not to be less than required by D 4.

1920 The section modulus of beams is not to be less than required by 1908 but is also to satisfy the requirements of D 8.

Tunnels and Recesses

1921 The scantlings and arrangements of tunnels, horizontal and longitudinal steps and recesses generally are to be equivalent to the requirements for boundary bulkheads.

Ventilators

1922 Ventilators from deep tanks passing through a 'tween deck are to be strong enough to withstand the pressure to which they may be subjected and they are to be made watertight.

Welded Connections

1923 Welded connections are to be in accordance with the requirements of Table D 32.1.

Special Requirements for Oil Fuel Tanks in Refrigerated Ships

1924 Where the hold above a double bottom tank carrying oil fuel is used for refrigerated cargo, the tank side brackets and floor plates are to be attached to the margin plate by welding, and gussets are to be welded to the margin plate. The connections of hold pillars, including heel doubling plates, also of the floors and intercostal plates under the pillars to the inner bottom, are to be welded. The attachments of manhole covers are not to pass through the inner bottom plating.

1925 For the requirements for protection of oiltight bulkheads, decks and inner bottom in way of refrigerated holds, see E 345 and E 346.

Protection and Drainage in Tanks Carrying Oil Fuel or Lubricating Oil

1926 Compartments carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying fresh or feed water. Oil fuel or lubricating oil compartments are to be similarly separated from those carrying vegetable oil. Cofferdams are to be suitably ventilated.

For tanks carrying vegetable and similar oils, see 1931.

1927 Gutterways are to be arranged at the foot of bulkheads in boiler rooms to ensure that leakage shall have free drainage to the wells or limbers.

1928 Drip trays or gutterways with suitable draining arrangements are to be provided for all tanks which do not form part of the hull structure, at pumps, valves and elsewhere where there is a possibility of leakage.

Drip trays are also to be fitted under oiltight decks, except if these are completely welded, when the drip trays need only be fitted over boilers and exhaust pipes.

1929 If cargo is carried in a compartment adjacent to an oil fuel settling tank which may be heated, the compartment side of the bulkhead or deck is to be insulated or equivalent arrangements provided.

Tanks Carrying Vegetable and Similar Oils

1930 The ventilation, drainage and control are to be generally as required for oil fuel tanks.

1931 Deep or peak tanks carrying vegetable or similar oils are to be separated from those carrying oil fuel, lubricating oil or fresh or feed water by a cofferdam.

Cofferdams are not required between oil fuel double bottom tanks and deep tanks above provided the inner bottom plating is not subjected to a head of oil fuel.

1932 All erection holes in knees, brackets, etc., are to be closed effectively. See Table D 32.1, Note 5, regarding welding.

Testing

1933 Tanks are to be tested by a head of water equal to the maximum to which the tank may be subjected, but not less than 2.44 m (8 ft) above the crown of the tank.

Topside tanks are to be tested either by testing each tank in accordance with the above or water testing one tank on each side of the ship and air testing the remainder. The air test is to be in accordance with D 5202. The tanks to be water tested are to be selected by the Surveyor.

When a preservative coating is to be applied to the internal structure of a tank, the water testing may take place after the application of the preservative, provided the structure is carefully examined to ensure that all welding and structural stiffening is completed prior to the application of the coating, and any riveted shell seams are tested with a high pressure hose test on the berth before coating. The hose test of the riveted seams may be carried out from the outside to avoid wetting the tank structure. As an alternative to hose testing, a leak test as described in D 5202 would be accepted.

The cause of any discoloration or disturbance of the coating is to be ascertained and any deficiencies repaired.

The attachment of fittings to oiltight surfaces should be completed before tanks are tested.

Loading Certificates

1934 When a loading certificate is requested, before a cargo of oil is loaded the tank should be tested under pressure and examined for cleanness to ensure that it is in a proper condition to receive the oil cargo.

In special circumstances the Committee will be prepared, with the consent of all interested parties, to consider alternative arrangements in respect of the testing of these tanks.

Cross-references

1935 For side frames in deep tanks, see D 7.

For reductions when an approved system of corrosion control is fitted, see D 110.

For hatch covers, see D 2638.

For air and sounding pipes, see D 29.

For pumping and piping arrangements, see Chapter E.

Section 20

WATERTIGHT TUNNELS

Tunnels

2001 Where a machinery space is situated with a compartment or compartments between it and the after peak bulkhead, the shafting is to be enclosed in a water-tight tunnel large enough to permit proper examination and repair of shafting. A sliding watertight door, capable of being operated locally on both sides of the door, is to be provided at the forward end of the tunnel. See D 2113.

Pipe tunnels are to have dimensions adequate for reasonable access.

Plating

2002 The thickness of tunnel plating is to be determined from D 1809. The thickness of plating derived from D 1809 may be reduced by 10 per cent for top plating where it is well curved.

If the top of the tunnel is flat the plating is to be not less than 10 per cent thicker than required by D 1809.

2003 Under hatchways the top plating is to be increased by 2 mm (0.08 in), unless covered with wood not less than 50 mm (2 in) in thickness which is to be secured by fastenings which do not penetrate the plating.

Where it is intended to use plywood or other forms of ceiling of an approved type instead of planking, the thickness will be considered in each case.

Stiffeners and End Attachments

2004 The scantlings of stiffeners are to be determined from D 1814 taking $\omega_1 = 1$ and $\omega_2 = 1$ in the appropriate formula. The span of the stiffener l is to be taken as the overall height of the tunnel, measured vertically at the centreline of the tunnel.

Where the tunnel top is flat, scantlings of the top stiffeners are also to satisfy D 8 where appropriate.

The lower end connection to the tank top is to be welded. See Table D 32.1.

Tunnels in Deep Tanks

2005 When tunnels form boundaries of deep tanks the requirements of D 19 are to be applied where appropriate.

Local Strengthening

2006 Additional strengthening is to be fitted under the heels of pillars or masts stepped on the tunnel.

The strength of bulkheads in way of watertight doors is to be maintained. See D 1811.

Ventilators

2007 Tunnel ventilators are to have scantlings suitable for the pressure to which they may be subjected and are to be made watertight.

Testing

2008 Tunnels are to be hose tested on completion.

Passageways

2009 Where fore and aft underdeck passageways are arranged at the ship's side, the after access thereto is to be by a watertight trunk led to the upper deck. Alternative arrangements to prevent the engine room being flooded in the event of a collision if the passageway doors are left open will be considered.

Section 21

MACHINERY SPACES

Engine Seatings

2101 The main engine scating should, in general, be integral with the double bottom structure; this particularly applies to higher power diesel or turbine installations. The tank top in way of the engine foundation should be substantially increased in thickness.

If the main machinery is supported on built-up seatings, the scantlings of these seatings are to be appropriate to the size of the machinery. Adequate transverse stiffening, in the form of tripping brackets in line with floors, is to be provided. Care must be taken to ensure continuity in strength between the longitudinal girders under the seating and the ship longitudinal girders. See D 920 and D 928.

2102 The plating under the foremost shaft tunnel bearing is to be increased in thickness and is to be scarphed into the heavy plating under the engine bedplate.

Boiler Bearers

2103 Boiler bearers are to be of substantial construction and efficiently supported by transverse brackets and longitudinal girders. See D 910 and D 922.

Clearance between Bulkheads and Boilers

2104 Bulkheads are to be kept well clear of boilers and uptakes, and sufficient space is to be allowed all around boilers for proper access and ventilation.

2105 Decks or flats and the tops of recesses are, in general, to be not less than 1,2 m (4 ft) clear of the boiler top. Uptakes and flat surfaces of boilers are to be not less than 0,450 m (1 · 48 ft) and the cylindrical shells of boilers not less than 230 mm (9 in) from bunker or hold bulkheads.

Exposed Casings Protecting Machinery Openings

2106 The scantlings of exposed casings protecting machinery openings are to be in accordance with D 1706 or D 1707.

2107 Doors in exposed machinery casings giving direct access to machinery spaces are to be of steel and weather-tight. They are to be permanently attached to the bulkhead by means of hinges and capable of being operated from both sides.

The door sills are not to be less than 600 mm (23.5 in) high if situated on the freeboard deck and not less than 380 mm (15 in) high on the superstructure deck.

In cargo ships of Type B-100 (see D 2604) means of access in exposed machinery casings on the freeboard deck is to be in accordance with D 5606.

2108 Cross ties may be required in way of particularly large deck openings.

Protected Casings

2109 Protected machinery casings are to have scantlings not less than:—

Plating in way of cargo spaces, thickness t=6.5 mm $(0\cdot25$ in)

,, ,, ,, accommodation spaces, thickness t = 5 mm (0.20 in)

Where the spacing of stiffeners exceeds 760 mm (30 in) the plating thickness is to be increased at the rate of 0,25 mm per 76 mm (0.01 in per 3 in) increase.

Stiffeners are to have a section modulus not less than:-

$$\frac{I}{\textbf{y}} = 0.008 \; \text{ls cm}^3 \qquad \left(\frac{I}{\textbf{y}} = 0.004 \; \text{ls in}^3\right)$$

where l = length of stiffener in metres (feet), $\mathbf{s} = \text{stiffener spacing in mm (in)}.$

- 2110 Where casing side stiffeners carry loads from decks above, or where they are in line with pillars below they are to be suitably increased.
- 2111 Where casing sides act as girder webs supporting tiers of decks above, care must be taken when cutting access openings to ensure that web continuity is maintained. Particular attention should be paid to stiffening where supporting funnel and exhaust uptakes in motor vessels.

Skylights

2112 Engine room skylights, where fitted, are to be substantially constructed and are to be securely connected to the coamings. Gratings over machinery room openings are to be protected by hinged plate covers, which are to be weathertight if the level of the openings is less than 600 mm (23·5 in) above the top of the hatch coamings required by D 2626. See also F 336.

Means of Escape

2113 In machinery spaces, two means of escape, one of which may be a watertight door, shall be provided from each engine room, shaft tunnel and boiler room. In machinery spaces where no watertight door is available, the two means of escape shall be formed by two sets of steel ladders as widely separated as possible leading to doors in the casing similarly separated and from which access is provided to the lifeboat embarkation deck. In the case of ships of less than 2000 tons gross, this requirement may be dispensed with, due regard being paid to the width and the disposition of the casing.

Communications

2114 Two means of communication are to be fitted between the bridge and the engine room.

Aluminium Alloy

2115 When aluminium alloy is used in the construction of the boundaries of the machinery space or in the casings or pillars, suitable insulation is to be fitted so that the structure remains effective in the presence of intense heat. The extent of the insulation is to be governed by the fire risk on either side of the boundary.

Additional Strengthening in Machinery Space

2116 Additional transverse strengthening is to be provided by means of web frames (see D 718) and strong beams, with suitable pillaring or other arrangements.

Machinery Spaces at Aft End of Ship

2117 Where applicable, D 55 is to be used for the construction of machinery spaces in this position.

Cross-references

2118 For passenger ships, see F 807, F 812 and F 814. For gutterway and drip trays, see D 1927 and D 1928.

Section 22

RUDDERS

Materials

2201 Steel castings are to comply with the requirements of P 5.

2202 Forgings are to comply with the requirements of P 6.

Rudder Stock

2203 The diameter of the rudder stock at and below the lowest bearing is not to be less than given by the following formula. For the minimum diameter of stock above the lowest bearing a in the formula is to be taken equal to zero.

(i) Ahead condition:—

$$d_{s} = 83.3 \text{ k } \left(\sqrt[3]{(V+3)^{2}} \sqrt{A^{2} S^{2} + a^{2}}\right) \text{ mm} \quad (1)$$

$$\left(d_{s} = k \left(\sqrt[3]{(V+3)^{2}} \sqrt{A^{2} S^{2} + a^{2}}\right) \text{ in}\right)$$

where $A = \text{rudder area, in } m^2 \text{ (ft}^2)$

S = horizontal distance, in metres (feet), from the centreline of the rudder pintles, or axle, to the centre of pressure of the rudder area, but is not to be less than 12 per cent of the breadth of the rudder.

For non-rectangular rudders the minimum value is to be taken as:—

$$0.12 \times \text{Area in m}^2 \text{ (ft}^2)$$

Depth on centreline of stock, in metres (feet)

For rectangular rudders, the centre of pressure may be taken at one-third of the breadth of the rudder from its leading edge.

For the astern condition, see (ii),

- V = the maximum service speed, in knots, with the ship in the loaded condition,
- k = 0.248 for rudders working in a propeller slipstream and 0.235 for rudders situated on the centreline of twin screw ships.
 For the astern condition, see (ii),
- a = a value depending upon the rudder support arrangement and is equal to zero when two or more pintles are fitted.

When one or no pintles are fitted:-

$$a = A_1 \left(\frac{l_1}{1,5} + \frac{l_2}{6} \right) - A_2 \left(l_1 + \frac{l_3}{2} \right)$$
 (2)

A, and A, are areas measured, in m2 (ft2),

 l_1 , l_2 and l_3 are measured at the centreline of the rudder stock, in metres (feet).

Note. When not otherwise shown in Fig. D 22.1 the various values in formula (2) for a are to be set equal to zero.

(ii) Astern condition:

The rudder stock diameter is to be calculated for the astern condition using the formula given in (i), where:—

V = astern speed, in knots. Unless special service conditions apply, the ship astern speed should be taken as half the speed ahead,

k = 0.185

The centre of pressure of the rudder is to be taken at $0.25 \times$ the breadth of the rudder from the aft edge.

Rudder Couplings

2204 Bolts in horizontal couplings are to have a diameter not less than:—

$$d_b = \frac{0.65 d_s}{\sqrt{n}} \quad mm \text{ (in)} \tag{1}$$

and the first moment of area of the bolts about the centre of the coupling is not to be less than:—

$$M = \frac{0.71 \text{ n d}_{s} \text{ d}_{b}^{2} \text{ cm}^{3}}{1000}$$

$$(M = 0.71 \text{ n d}_{s} \text{ d}_{b}^{2} \text{ in}^{3})$$

where d_b = bolt diameter, in mm (in),

d_s = rudder stock diameter obtained from 2203, in mm (in),

n= number of bolts but not to be less than six. The thickness of the coupling flanges is not to be less than d_b mm (in).

2205 Vertical couplings are to have not less than eight securing bolts each having a diameter not less than:—

$$d_b = \frac{0.81d_s}{\sqrt{n}} \text{ mm (in)}$$
 (1)

and the first moment of area of the bolts about a vertical axis through the centre of the coupling is not to be less than:—

$$M = \frac{0.43 d_S^3}{1000} \text{ cm}^3 \quad (M = 0.43 d_S^3 \text{ in}^3)$$
 (2)

where db, ds and n are as specified in 2204.

2206 The width of material in coupling flanges outside the boltholes is not to be less than two-thirds of the rule bolt diameter.

2207 Coupling bolts are to be fitted and suitable arrangements are to be made to lock the nuts.

Rudder Pintles

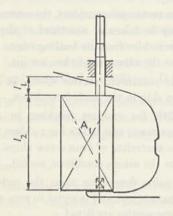
2208 Rudder pintles are to have a diameter not less than:—

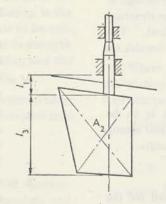
$$d_P = 31 + 4,17 \text{ V } \sqrt{A_P \text{ mm}}$$

 $(d_P = 1.22 + 0.05 \text{ V } \sqrt{A_P \text{ in}})$

where d_p = pintle diameter (measured outside liner, if fitted),

V = ship speed but is not to be taken as less than 10 knots,





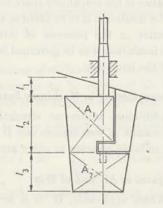


Fig. D 22.1

A = total rudder area, in m2 (ft2),

Ap = rudder area supported by the pintle—see Fig. D 22.2, but need not be taken greater than A, and for rudders with two or more pintles (except semi-spade rudders as shown) is to be taken as the total area of rudder divided by the number of pintles.

2209 The bearing length of pintles in their gudgeons and housings is, in general, to be 20 per cent greater than the diameter of the pintle obtained from 2208, but for very large pintles may be less, provided that the bearing pressure is not greater than:—

Metal bearings 70 kg/cm² (996 lb/in²)

Lignum vitæ or

synthetic bearings.... 56 kg/cm² (796 lb/in²)

based on the projected area (i.e., length × diameter).

The force acting on the bearing may be taken as

$$F = \frac{A_P (V + 3)^2}{100} \text{ tonnes}$$

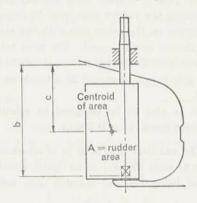
$$\left(\mathsf{F} = \frac{\mathsf{A}_{\mathsf{P}} \; (\mathsf{V} + 3)^2}{1095} \; \mathsf{tons}\right)$$

where Ap is as derived from 2208

In no case is the bearing length to be less than the pintle diameter. The width of material in the gudgeons (measured outside the bushing if fitted) is not to be less than 50 per cent of the rule pintle diameter, but need not normally exceed 125 mm (4.9 in).

2210 Pintles are to have a taper of 1 in 12 on radius.

The bottom pintle on semi-spade type rudders is to be keyed to the rudder or sternframe gudgeon as appropriate.



For lower pintle
$$A_p = \frac{A \times C}{b}$$

2211 The pintle clearances with metal bearings should not be less than 1 mm (0.04 in) on the diameter and with synthetic bushes should not be less than 1,5 mm (0.06 in).

2212 Synthetic rudder bearing materials are to be of a type approved by the Society. When this type of lining material is used, an adequate supply of water to the bearing is to be provided.

2213 Where it is proposed to use stainless steel for liners or bearings the chemical composition is to be submitted for approval.

2214 The distance between the lowest rudder stock bearing and the upper pintle should be as short as possible.

2215 Where liners are fitted to pintles they are to be shrunk on or otherwise efficiently secured.

Rudder Plating

2216 Rudder side plating in double plated rudders is to have a thickness not less than:—

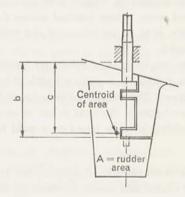
$$t = \frac{b_1 + 610}{1000} \left(4 - \frac{b_1}{s} \right) \left(1,45 + 0,1 \ \sqrt{d_8} \right) \ mm$$

$$\left(t = \frac{\mathsf{b_1} + 24}{1000} \left(4 - \frac{\mathsf{b_1}}{\mathsf{s}}\right) \left(1 \cdot 45 + 0 \cdot 504 \; \sqrt{\mathsf{d_s}}\right) \; \mathrm{in}\right)$$

where b₁ = spacing, in mm (in), of the horizontal webs, and is not to exceed 1220 mm (48 in),

s = spacing, in mm (in), of the vertical webs and is not to be taken as less than b₁ in the formula. In general, s is not to exceed 2 b₁ in any panel,

d_s = diameter of rudder stock, in mm (in), required by 2203.



For upper pintle A_P = (A-lower pintle A_P) but not less than 0.35A.

2217 Vertical and horizontal webs are to have the same thickness as the side plating. See also 2219 for vertical webs forming mainpiece.

2218 Nose plates are to have a thickness not less than 25 per cent greater than that required for side plating but need not exceed 22 mm (0·87 in). Top and bottom plates are to have the thickness derived from 2216 with b₁ taken as the maximum rudder width at top or bottom but not less than 900 mm (35·4 in). In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.

Mainpiece

2219 Fabricated mainpieces may be of rectangular or tubular section. The breadth and width of rectangular mainpieces are not to be less than the diameter required by 2203. The thickness of the side plating and vertical webs that form a rectangular mainpiece are not to be less than:—

$$t_{\rm m} = 8.5 + 0.56 \sqrt{d_{\rm s}} \text{ mm},$$

 $(t_{\rm m} = 0.335 + 0.112 \sqrt{d_{\rm s}} \text{ in}),$

but need not exceed 25,5 mm (1.0 in).

The increased side plating is to have a minimum fore and aft extent of 20 per cent of the rudder breadth and is to be attached to the two vertical webs forming the mainpiece.

Tubular mainpieces are to have an inside diameter not less than required by 2203, and a thickness not less than $t_{\rm m}$ mm (in) as given in the previous sub-paragraph, but need not exceed 25,5 mm (1·0 in). When tubular mainpieces are fitted, the rudder side plating in way may be as required by 2216.

General

2220 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds on to flat bars on the webs.

The slots are to have a minimum length of 75 mm (3 in) and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded.

The space between the slots is not to exceed 150 mm (6 in) and welding is to be based on a weld factor of 0.44 (0.63).

2221 Internal surfaces of double plate rudders are to be efficiently coated and means for draining the rudder are to be provided.

2222 Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted.

- 2223 Suitable arrangements are to be provided to prevent the rudder from lifting.
- 2224 Where bow rudders are fitted for use when going astern, they are to have a locking device to ensure that the rudder is kept in the central position when the ship is going ahead.
- 2225 When the weight of the rudder is supported by a carrier bearing attached to the rudder head the structure in way is to be adequately strengthened for that purpose. The plating under all rudder head bearings or rudder carriers is to be increased in thickness.
- 2226 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required, and the rudder is to be reinforced in way of these openings.

Testing

2227 Double plated rudders are to be tested by a head of water of 2,44 m (8 ft) or equivalent.

Cross-reference

2228 For strengthening for navigation in ice, see D 24.

Section 23

STEERING GEAR

General

2301 All ships are to be provided with two independent means of moving the rudder. In passenger ships and in cargo ships of 500 tons gross and above, one of the gears is to be operated by power. All gears are to be fitted and tested under working conditions to the satisfaction of the Surveyors.

2302 The power operated main steering gear is to be capable of putting the rudder over from 35 degrees on one side to 35 degrees on the other side with the ship running ahead at maximum service speed. The time taken to put the rudder over from 35 degrees on either side to 30 degrees on the other side is not to exceed 28 seconds at maximum service speed.

The gear is also to be designed in relation to the maximum astern speed. (See D 2203.)

- 2303 The auxiliary gear is to be of adequate strength and sufficient to steer the ship at navigable speed and is to be capable of being brought speedily into action in an emergency.
- 2304 In cargo ships a power operated auxiliary gear is to be fitted where the Rule diameter of the rudder stock at the tiller, corresponding to a speed of 10 knots, is 250 mm

(10 in) and above. Where main steering gear power units and their connections are fitted in duplicate and the duplicate units acting together satisfy the requirements of 2302, and each power unit separately satisfies the requirements of 2303, an auxiliary gear will not be required.

2305 In passenger ships, the auxiliary gear is to be power operated if the Rule diameter of rudder stock at the tiller exceeds 230 mm (9 in). When main steering gear power units and their connections are fitted in duplicate and each power unit separately is capable of satisfying the requirements of 2302, an auxiliary gear will not be required.

2306 In passenger ships, where the Rule diameter of the rudder stock at the tiller exceeds 230 mm (9 in), an alternative steering position remote from the main steering position is to be provided. The steering control systems from the main and alternative steering stations are to be arranged so that failure of either system would not result in inability to steer the ship by means of the other system.

Means are to be provided to enable orders to be transmitted from the bridge to the alternative steering station.

2307 The exact position of the rudder, if power operated, shall be indicated at the main steering station.

2308 The after steering wheel and gear in oceangoing ships are to be adequately protected or situated in such a position that protection can be dispensed with.

2309 The steering gear is to be secured to the seating by fitted bolts and suitable chocking arrangements are to be provided.

Tillers and Quadrants

2310 Tillers and quadrants are to be shrunk on or bolted to the rudder stock. The shrinkage allowance is to be between 1/550 and 1/700 of the diameter of the rudder stock in way. When the tiller and quadrant are bolted, or when a shrinkage less than given above is used, a key having an effective sectional area in shear not less than $\frac{0.25\,{\rm d_s}^2}{100}\,{\rm cm}^2$ (0.25 ${\rm d_s}^2$ in²) is to be fitted. The keyways are to have rounded ends.

2311 The section modulus of the tiller arm at any point within its length taken about a vertical axis, is not to be less than the greater of the following:—

For a single arm tiller

(i)
$$\frac{I}{y} = \frac{0,15d_s^3 (a-b)}{1000a} \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{0.15d_s^3 (a-b)}{a} \text{ in}^3\right)$$

(ii)
$$\frac{I}{y} = \frac{0.06d_s^3 (a-0.9d_s)}{1000a} cm^3$$

$$\left(\frac{I}{y} = \frac{0.06d_s^3 (a-0.9d_s)}{a} in^3\right)$$

Where d_s = diameter of rudder stock, in mm (in), at the tiller head, as obtained from D 2203.

> a = distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm (in),

> b = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm (in).

Note. a and b are to be measured with zero rudder angle.

Where more than one arm is fitted the combined modulus of the arms is not to be less than as required above.

For solid tillers the breadth to depth ratio is not to be more than 2.

2312 The depth of the boss is not to be less than the diameter of the rudder stock d_s . The thickness of the boss in way of the tiller is not to be less than $0.4d_s$.

2313 The diameter of bolts in bolted tillers or quadrants is not to be less than:—

$$d_b = \frac{0,60 \, d_s}{\sqrt{n}} \, \mathrm{mm} \, (\mathrm{in})$$

Where d_s is as defined in 2311, n = total number of bolts in the coupling.

Locking or Brake Gear

2314 An efficient locking or brake arrangement is to be fitted to all gears to keep the rudder steady when necessary.

In bow rudders where a vertical locking pin is operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

Rudder Stops

2315 Suitable stopping arrangements are to be provided for the rudder. Cut-outs on the steering engine are to be arranged to operate at a smaller angle of helm than those for the rudder.

Cross-reference

2316 For strengthening for navigation in ice, see D 24.

Section 24

STRENGTHENING FOR NAVIGATION IN ICE (GENERAL SERVICE)

Where the notation "Ice Class 1*, 1, 2 or 3" as specified in B 114 (a) is desired, the following requirements are to be complied with, so far as these are applicable.

(For northern Baltic service, see D 24A.)

Symbols

L = length of ship, in metres (feet), 2401

> L, = length of ship, in metres (feet), but need not be taken as greater than 215 m

B = moulded breadth, in metres (feet),

s = frame spacing, in mm. (in),

Sp = basic frame spacing, in mm (in), i.e., (i) aft of 0,2L from fore perpendicular to the after peak bulkhead:-

$$\frac{L_1}{0.6}$$
 + 510 mm $\frac{L_1}{0.6}$ + 20 in

$$\left(\frac{\mathsf{L}_1}{50} + 20 \ \mathrm{in}\right)$$

- (ii) forward of 0,2L from fore perpendicular to the fore peak bulkhead:as required by D 705, but is not to exceed the spacing required by (i) above.
- (iii) in peaks and cruiser sterns:as required by D 706.

tb = basic ice shell plating thickness, =

$$\left(5 + \frac{\mathsf{L}}{13,65}\right) \sqrt{\frac{\mathsf{s}}{\mathsf{s}_\mathsf{b}}} \ \mathsf{mm}$$

$$\left(\left(0,20 + \frac{\mathsf{L}}{1140}\right) \sqrt{\frac{\mathsf{s}}{\mathsf{s}_\mathsf{b}}} \ \mathsf{in}\right)$$

shp = maximum shaft horse power, see H 105.

2402 The vertical extent of ice strengthening is related to Light and Load waterlines which are to be determined as follows:-

Light waterline: is the lowest waterline, taking account of trim, at any point along the length of the ship corresponding to either of the following conditions:-

- (a) The lightest load condition in which the ship may be expected to be at sea in ice conditions,
- (b) The ballast condition.

Load waterline: is that corresponding to the winter load line. (For ships trading in the Baltic at the summer

load line, the ice strengthening is to be based on this load line. In these cases a suitable notation will be made in the Register Book.)

The position of maximum breadth on the winter load waterline is to be indicated on the plans.

FRAMING

Class 1*

2403 The frame spacing is not, in general, to exceed 610 mm (24 in) between the forward perpendicular and ·25L forward of amidships, and 800 mm (31.5 in) over the remainder of the length to the after peak bulkhead.

2404 Intermediate frames are to be fitted over the full length of the ship. The strength of these frames is to be the same as that of the adjacent Rule main or 'tween deck frames.

In way of deep tanks the section modulus of intermediate frames may be that of the main frames before the increase required by D 720 is applied.

In the panting region clear of deep tanks the intermediate frames may have a section modulus as derived from D 707 (2) but ignoring the factor f.

The intermediate frames are to extend from the upper deck, or from the second deck provided this is at least 750 mm (29.5 in) above the load waterline, to below the level of the top of floors or to a point just above the tank top where this runs horizontally to the ship's side, and need not be connected at their ends. Where the second deck is above the load waterline but less than 750 mm (29.5 in) above, the intermediate frames may terminate at a stringer situated not less than 1,2 m (4 ft) above the load waterline.

In the fore and aft peaks the main and intermediate frames are to have the same modulus as an amidship frame determined from D 707 (1) with a frame spacing equal to $\frac{L_1}{0.6} + 510 \text{ mm}$ $\left(\frac{L_1}{50} + 20 \text{ in}\right)$, or a modulus equal to twice that of the normal peak frames, whichever is the greater.

Where the frames terminate at the 2nd deck, and long or broad hatchways are fitted in this deck, the plating in way of the hatchways is to be suitably strengthened by fitting web frames or strong beams to give adequate support to the framing.

Class 1

2405 Intermediate frames are to be fitted over the full length of the ship. The strength of these frames is to be the same as that of the adjacent Rule main or 'tween deck frames, unless stringers are fitted in accordance with 2429 when the intermediate frames may be 75 per cent of the adjacent Rule frames.

In way of deep tanks the section modulus of intermediate frames may be that of the main frames before the increase required by D 720 is applied.

In the panting region clear of deep tanks the intermediate frames may have a section modulus as derived from D 707 (2) but ignoring the factor f.

The intermediate frames are to extend from 915 mm (36 in) below the light waterline to 750 mm (29.5 in) above the load waterline. They are to be connected at their ends to the adjacent frames by a horizontal member having the same scantlings as these frames, or equivalent arrangements are to be provided. Alternatively, they are to be carried down to within 255 mm (10 in) of the margin plate or, where the ship has no double bottom, to a point below the top of the floors. If the frames are so extended they need not be attached at the lower end.

In the fore and aft peaks the main and intermediate frames are to have the same modulus as an amidship frame determined from D 707 (1) with a frame spacing equal to $\frac{L_1}{0,6} + 510 \text{ mm} \left(\frac{L_1}{50} + 20 \text{ in}\right)$, or a modulus equal to twice that of the normal peak frames, whichever is the greater.

Class 2

2406 Intermediate frames are to be as required by 2405 except that they need only be fitted in the region from the forward perpendicular aft for a length equal to the distance from the forward perpendicular to the point where the load waterline reaches its greatest breadth plus 10 per cent of that distance.

Class 3

2407 For the longitudinal extent given in 2406 intermediate frames are to be fitted abaft the forward perpendicular. They are to extend from 915 mm (36 in) below the light waterline to 750 mm (29.5 in) above the load waterline, and need not be connected at their ends.

The intermediate frames forward of the collision bulk-head should have a modulus equal to 50 per cent of the Rule peak frames, and those aft of the collision bulkhead should have a modulus equal to 80 per cent of the adjacent Rule frames unless stringers are fitted in accordance with 2431. In this case the intermediate frames aft of the collision bulkhead should have a modulus equal to 75 per cent of the Rule peak frames, but in 'tween decks need not exceed the adjacent frame.

General

2408 For Ice Classes 1*, 1 and 2, frames are not to be scalloped, except at the seams in the shell plating, over the area defined in 2410.

2409 Attention is to be paid to the minimum thickness of frames and other stiffening members. In general, this should not be less than one-half that of the attached hull plating.

Where stringers are not fitted, brackets are to be arranged to prevent the frames from tripping.

SHELL PLATING

Class 1*

2410 From the forward perpendicular aft for a length equal to the distance from the forward perpendicular to the point where the load waterline reaches its greatest breadth plus 10 per cent of that distance, and extending vertically from 610 mm (24 in) below the light waterline to 750 mm (29.5 in) above the load waterline, the thickness of the shell plating is not to be less than 1,8 t_b mm (in).

2411 From this position to 0,25 \perp aft of amidships and over the same vertical extent, the thickness of shell plating is not to be less than 1,4 $t_{\rm p}$ mm (in).

If the parallel middle portion on the load waterline extends further aft than 0,25L aft of amidships, the shell plating over this parallel middle portion is also not to be less than 1,4 t_b mm (in).

2412 For the remainder of the length and over the same vertical extent, the thickness of shell plating is not to be less than 1,25 t_b mm (in).

2413 The side and bottom shell plating below this belt from the stem to a position five frame spaces abaft the point where the bow profile departs from the level keel line is not to be less than 1,8 t_b mm (in).

2414 The increased thickness need not exceed 32 mm (1.25 in), but is not to be less than 14 mm (0.55 in). Changes in thickness are to take place gradually.

2415 When the shp exceeds 2,26 $(L \times B)$, or in British units 0.21 $(L \times B)$, the shell plating for the longitudinal extent given in 2410 shall be increased by a further 1 mm (0.04 in) for each 500 shp excess over the above figure. (The shp is to be indicated on the plan on which the shell plating is approved).

Class 1

2416 For the longitudinal and vertical extent given in 2410 the thickness of the shell plating is not to be less than $1.5~t_{\rm b}$ mm (in).

2417 For the remainder of the length and over the same vertical extent the thickness of shell plating is not to be less than 1,25 $t_{\rm b}$ mm (in).

2418 The increased thickness need not exceed 25,5 mm $(1\cdot0)$ in), but is not to be less than 12,5 mm $(0\cdot5)$ in). Changes in thickness are to take place gradually.

Class 2

2419 For the longitudinal and vertical extent given in 2410 the thickness of the shell plating is not to be less than 1.5 t_b mm (in).

2420 For the remainder of the length and over the same vertical extent the thickness of shell plating is not to be less than 1,15 $t_{\rm b}$ mm (in).

2421 The increased thickness need not exceed 25,5 mm $(1\cdot0)$ in), but is not to be less than 12,5 mm $(0\cdot5)$ in). Changes in thickness are to take place gradually.

Class 3

2422 For the vertical extent given in 2410 and from the forward perpendicular to the point where the load waterline reaches its greatest breadth the thickness of the shell plating is not to be less than 1,25 t_b mm (in).

2423 For the remainder of the length, the thickness is to be normal Rule.

2424 The increased thickness need not exceed 25,5 mm (1·0 in), but is not to be less than 12,5 mm (0·5 in). Changes in thickness are to take place gradually.

STRINGERS

Class 1*

2425 Forward of the collision bulkhead the tiers of beams and stringers required by D 11 are to be spaced not more than 1,3 m ($4 \cdot 25$ ft) apart.

2426 Abaft the collision bulkhead the stringer next below the load waterline is to be extended over the full length of the ship, unless a deck is situated not more than 1,2 m (4 ft) below the load waterline, and the main and intermediate frames are to be attached thereto.

The stringers immediately above and below this stringer are also to be extended over the full length of the ship, but may be intercostal and of the same scantlings as the frames in way.

2427 Where the light waterline lies well above the margin a stringer may be required in the vicinity of the light waterline and over the full length of the ship.

2428 In single deck ships a stringer is to be arranged in the vicinity of the load waterline, over the full length of the ship.

Class 1 and Class 2

2429 The following requirements apply only when the intermediate frames are made 75 per cent of the adjacent Rule main or 'tween deck frames. See 2405.

Abaft the collision bulkhead stringers of the scantlings given in D 11 are to be fitted 2 m (6.56 ft) apart for the longitudinal extent given in 2410.

2430 The stringer-next below the load waterline is to be extended over the full length of the ship unless a deck is situated not more than 600 mm (23.5 in) below the load waterline, for Ice Class I only.

Class 3

2431 When the intermediate frames are made 75 per cent of the Rule peak frames (see 2407), stringers of the scantlings given in D 11 are to be fitted 2 m (6.56 ft) apart abaft the collision bulkhead for the longitudinal extent given in 2410.

General

2432 Attention is to be paid to the minimum thickness of stringers. In general, this should be not less than one-half that of the attached hull plating.

RUDDER & STEERING ARRANGEMENTS

2433 The diameters of the rudder head and pintles are to be increased above that required by D 22 by:—

Class 1* - 30 per cent,

Class 1 - 25 per cent,

Class 2 - 12,5 per cent,

Class 3 - 7,5 per cent.

2434 The side plating and webs of double plate rudders are to be increased above that required by D 22 by:—

Class 1* - 50 per cent,

Class 1 - 50 per cent,

Class 2 - 25 per cent,

Class 3 — 10 per cent.

2435 The gudgeons, remaining rudder items and couplings are to be based on the increased rudder head or pintle and the steering gear is to be suitably protected against, or designed to withstand, the increased loading.

In welded double plate rudders, the horizontal and vertical webs are not to be welded direct to the side plates, but are to be attached to flat bars or equivalent arrangements made to avoid hard points. 2436 The rudder head is to be protected by an ice knife, a suitable stern, or other equivalent arrangements—Ice Classes 1* and 1 only.

STERNFRAME

2437 The strength of the rudder horn, rudder post and solepiece and the diameter of the rudder axle (if fitted) are to be increased above the Rule requirements by:—

STEM

Class 1*

2438 The bow should be of a form specially designed for navigation in ice.

A solid stem of forged, rolled or cast steel is to be fitted up to 750 mm (29.5 in) above the load waterline.

General

2439 The sectional area of a solid stem bar is to be greater than Rule requirements by:—

The connections of the shell plating to the stem bar are to be flush.

2440 Where a plate stem is fitted, the thickness of the plates below a position 750 mm (29.5 in) above the load waterline is not to be less than:—

but need not exceed 25,5 mm (1.0 in).

 t_b is to be determined using $s = \frac{L_1}{0.6} + 510 \, \text{mm}$

$$\left(\frac{L_1}{50} + 20 \text{ in}\right)$$

The thickness may be tapered to that of the normal plate stem (see D 1205) at the upper deck. Plates which require to be furnaced are to have these thicknesses when finished. 2441 Below the load waterline, plate stems should be reinforced by a centreline web—Ice Classes 1* and 1 only—and by horizontal webs. The horizontal webs are to be spaced not more than 700 mm (27.5 in) for Class 1* and 915 mm (36 in) for other classes.

GENERAL

Cross-reference

2442 For machinery requirements, see H 5.

Section 24A

STRENGTHENING FOR NAVIGATION IN ICE (NORTHERN BALTIC SERVICE)

When ice class notations as specified in B 114(b) are desired, the ship is to comply with the following requirements (given in metric units only) which are generally identical with those for the corresponding notations in Annex I of the "Finnish-Swedish Ice Class Rules 1971". In no case, however, should scantlings be less than those required by the Rules for ordinary sea-going service.

It should be noted that not even ships built to Ice Class IA Super can withstand heavy ice jamming. Also that small ships will be unable to navigate in as severe ice conditions as larger ships having the same ice class, because of their weaker hull and less engine power.

Definitions

2460 The "ice belt" is that part of the shell plating which has to be reinforced.

The load waterline, LWL, is that corresponding to the winter load line. For ships trading in the Baltic at the summer load line, the ice strengthening is to be based on this load line.

The ballast waterline, BWL, is to be determined in such a way that the propeller, if possible, is wholly submerged. The corresponding forward draught is to be calculated, taking into account a normal amount of fuel and a suitable amount of water ballast. A relatively narrow ice belt will be approved if ballasting arrangements are satisfactory. The load and ballast waterlines are to be indicated on the shell expansion plan.

The displacement, V, is that related to the summer load line assigned, in tonnes. (Specific gravity of water = 1,0.)

The shaft horse power, H, is the maximum shaft horse power, as defined in H 105.

Chapter D

Assumed Ice Pressures

2461 Scantlings of frames and plating are determined by formulae based on the pressure between the ship's hull and the ice. As the pressure is higher forward than amidships and aft, the ice belt of the ship has been divided into three regions as follows:—

FORWARD: From the stem to a line parallel to and 0,04L aft of the border line of the flat side of hull forward.

MIDSHIP: From the above defined line to a line parallel to and 0,04L aft of the border line of the flat side of hull aft.

Aft: From the aft boundary of the midship region defined above to the stern.

The above regions are to be indicated on the shell expansion plan.

(L = length between perpendiculars.)

For the four ice classes the pressure, p, in the three regions on the ice belt is as follows:—

FORWARD

IA Super: p = 6.4+0.73k; max. 16.5 kg/cm^2 IA : p = 5.8+0.64k; max. 15.0 kg/cm^2 IB : p = 5.2+0.55k; max. 13.5 kg/cm^2 IC : p = 4.6+0.46k; max. 12.0 kg/cm^2

MIDSHIP

IA Super: p = 5.7+0.21k: max. 8.6 kg/cm^2 IA : p = 4.6+0.14k; max. 6.9 kg/cm^2 IB : p = 3.5+0.07k; max. 4.6 kg/cm^2 IC : $p = 2.4 \text{ kg/cm}^2$

AFT

IA Super: p = 4.6+0.13k; max. 6.3 kg/cm^2 IA : p = 3.5+0.09k; max. 4.6 kg/cm^2 IB : p = 2.4+0.05k; max. 2.9 kg/cm^2

IC : $p = 1.2 \text{ kg/cm}^2$

where $k = \frac{\sqrt{V H}}{1000}$

V and H are as defined in 2460.

Where a calculated p value exceeds the given maximum value, the latter may be used in the formulæ.

The k and p values used are to be stated on shell expansion and framing plans.

Transverse Framing

2462 The strength of transverse main and intermediate frames is to be determined by the formula:—

$$\frac{I}{y} = \frac{p \, s \, (l\!\!-\!\!400)}{8 \, f_y} \ \mathrm{cm}^3$$

where $\frac{I}{y}$ = section modulus of the frame (including a width of attached plating equal to s),

p = pressure in the relevant region, as determined by 2461,

s = distance, in mm, to the adjacent intermediate frame, or main frame if intermediate frames are not fitted,

I = span, in mm, measured along the frame,

f_y = yield stress of the steel, in kg/cm². (For ordinary steel the value 2400 kg/cm² is to be used in all formulæ concerning framing and plating.)

The Rule frame spacing may be modified to enable minimum increase in hull weight to be achieved.

Where end connections of intermediate frames differ from those of the main frames, giving different spans, the mean span is to be used when determining main and intermediate frames. See Figs. D 24.1, D 24.2 and D 24.3, also 2482.

2463 The minimum vertical extension of transverse ice framing is to be as given in Table D 24.1.

Upper End of Framing

2464 Where not terminating at or above a 'tween deck, as indicated in 2465 and 2466, the upper end of intermediate frames is either to be extended to the deck above or to be attached to an ice stringer as in 2482. See Fig. D 24.1.

2465 Where the ice framing terminates 1000 mm or less above a 'tween deck, the above-deck part of the frames may have the scantlings of Rule 'tween deck frames. The upper end of intermediate frames is to be connected to the adjacent main frames by a horizontal member having the same scantlings as the main frames. Where the ice framing terminates less than 250 mm above a 'tween deck, the top part of intermediate frames may be omitted. See Fig. D 24.2.

2466 Where the ice framing terminates more than 1000 mm above a 'tween deck, the ends of main and intermediate 'tween deck frames are either to be attached to an ice stringer or to be extended to the deck above and may in that case be determined by the formula:—

$$\frac{\rm I}{\rm y} = \frac{\rm p\,s\,d\,(\it l\!-\!400)\,(\it l\!-\!d)}{2\,\,{\rm f_y}\,\it l^2}\,{\rm cm^3} \quad . \label{eq:psd}$$

where d, in mm, is as indicated in Fig. D 24.3.

For Ice Class IA Super, (d+250) mm is to be used instead of d in the formula.

TABLE D 24.1

CLASS	EXTENT	Position	
		Above LWL	Below BWL
IA Super	From stem to 0,3L	1200 mm	to double bottom or below top of floors
	Abaft 0,3L and Midship	1200 mm	1600 mm
	Aft	1200 mm	1200 mm
IA, IB and IC	From stem to 0,3L	1000 mm	1600 mm
	Abaft 0,3L and Midship	1000 mm	1300 mm
	Aft	1000 mm	1000 mm

If d, or (d+250) as applicable, exceeds half the span I, the formula given in 2462 is to be used.

Where d is equal to or less than one-third of *I*, the end of intermediate frames may terminate not more than 25 mm below the deck, and need not be connected by a horizontal member.

Note. If the section modulus derived as above is less than that required by D 7, the latter is to be used.

Lower End of Framing

2467 The lower end of intermediate frames is, except as indicated in 2468, either to be extended to approximately 25 mm above the margin plate or a corresponding distance below top of floors, or to be attached to a tank top, deck, or ice stringer. The ends are to be connected to adjacent brackets, floors or main frames by a horizontal member having the same scantlings as the main frames. See Fig. D 24.3.

2468 Where the ice framing terminates less than 1000 mm below a deep-tank top, or a deck or an ice stringer, the intermediate frame ends may be attached to adjacent main frames by a horizontal member as above. Where the distance is less than 250 mm, intermediate frames may terminate at a deep-tank top or deck. See Fig. D 24.2.

Alternatively, the section modulus may be determined as required by 2466, where this is appropriate.

2469 In general, ice strengthened main frames are to extend to the bottom construction, but main frames below

a deck, deep-tank top or ice stringer situated at least 600 mm below the BWL need only be of Rule scantlings.

2470 In twin-screw ships three intermediate frames forward of and three aft of the propeller blade tips are to extend to the double bottom.

The different parts of a frame are to be efficiently welded together. Frames are to be effectively attached to decks and stringers.

Longitudinal Framing

2471 The strength of longitudinal frames is to be determined by the formula:—

$$\frac{I}{y} = \frac{p_2 \, \mathit{l}^2 \, s}{13\,000 \, f_y} \, \mathrm{cm}^3$$

where $p_2 = 0.64 p$ in the forward region, and = 0.70 p in the midship and aft regions,

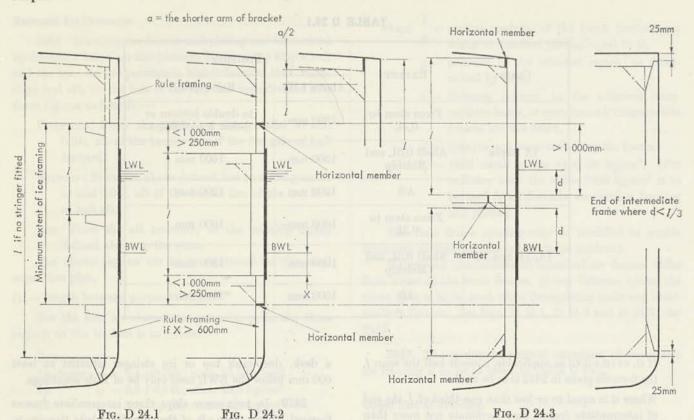
p, l, s, fy are as defined in 2462,

I = section modulus of longitudinal (as defined in 2462).

The end connections of intermediate frames are to be the same as for the main frames.

The spacing of longitudinal frames may be chosen to enable minimum increase in hull weight to be achieved.

Intermediate frames are to be fitted above the upper edge and below the lower edge of the ice belt, strengthening the area to the same vertical extent as with transverse framing. See 2463.



Framing General

2472 Where the span, *l*, of a frame is divided by the border line between two regions, the higher pressure in 2461 is to be used in 2462, 2466 and 2471.

2473 Main and intermediate frames calculated for a pressure, p, exceeding 4,6 kg/cm², and which are welded to the shell plating, are to be supported by stringers, intercostals, brackets or similar, in order to prevent tripping. The distance between the tripping arrangements is not to exceed 1300 mm. See Fig. D 24.4.

2474 Main and intermediate frames, calculated for a pressure, p, equal to or exceeding 4,6 kg/cm², are not to be scalloped except at shell plating seams or butts, but are to be attached to the shell plating by double continuous welds. The thickness of the frames is to be at least half that of the attached shell plating with a minimum of 10 mm.

2475 Where, instead of an ice strengthened main or intermediate frame, a bulkhead or a platform deck is fitted, the thickness of which is less than that of the omitted frame, the border part of the bulkhead or the platform is to be made of steel plate at least as thick as the frame and so wide that the section of the border plate is equal to that of the frame.

Shell Plating

2476 The thickness of shell plating, t, in association with transverse framing is to be determined by the formula:—

$$\begin{split} t &= \frac{2\,\text{s}}{3}\,\sqrt{\frac{p_3}{\text{fy}}} + 2\,\text{mm} \\ \text{where } p_3 &= 1.2\,\text{p}\,\Big(1.1 - \frac{\text{s}}{3000}\Big), \text{ but need not} \\ \text{exceed } 16.5~\text{kg/cm}^2, \end{split}$$

p, s and f, are as defined in 2462.

The plating thickness is not to be less than that required by D 5 or D 43 as appropriate, but the frame spacing may be increased and the framing recalculated.

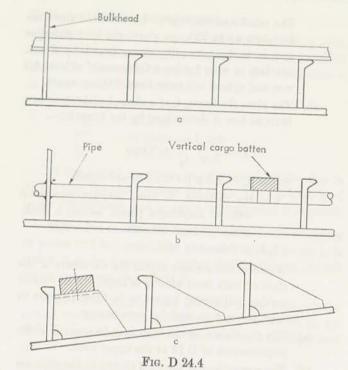
2477 The thickness of shell plating, t, in association with longitudinal framing is to be determined by the formula:—

$$t = \frac{2s}{3} \sqrt{\frac{p_4}{f_y}} + 2 mm$$

where $p_4 = 1.4 p$ in the forward region, and

= 1,2 p in the midship and aft regions, but need not exceed 16,5 kg/cm²,

p, s and f_y are as defined in 2462.



2478 The vertical extension of the ice belt is to be, for Ice Class IA Super, from 750 mm above LWL to 600 mm below BWL, for Ice Class IA from 600 mm above LWL to 500 mm below BWL, and for Ice Classes IB and IC from 500 mm above LWL to 500 mm below BWL.

2479 The bottom plating and floors in the forward region are to be adequately strengthened, where the distance from the lower edge of the ice belt to the keel plate is less than 1500 mm or where the draught is less than 1500 mm.

2480 Changes in plating thicknesses in longitudinal direction are to take place gradually.

Decks and Ice Stringers

2481 The strength of decks adjacent to hatchways and supporting the ice framing is to be determined by the formula:—

$$\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{p~K~S^2}}{\mathrm{22~f_y}}\,\mathrm{cm^3}$$

where $\frac{\mathbf{I}}{\mathbf{v}} = \text{section modulus of the deck or ice stringer,}$

$$K = 1.1 - \frac{S}{10\,000},$$

$$K_{\text{max}} = 1.0$$
 $K_{\text{min}} = 0.7$

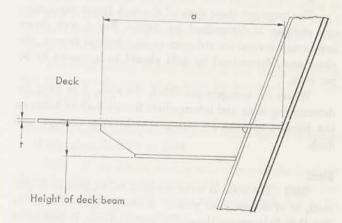
S = transversely unsupported length of hatchway, in mm,

p and fy are as defined in 2462.

The product p K is not to be taken less than 7 kg/cm². If p K \geq 4800 $\frac{t^3}{r^2}$ kg/cm², the deck is to be supported at intermediate frames and by partial beams or brackets in accordance with Fig. D 24.5; r being the deck beam spacing, in mm.

The required shear area, A, of the deck in way of hatch corners is not to be less than:—

$$\mathsf{A} = \frac{4.2\;\mathsf{p\;K\;S}}{\mathsf{f_y}}\;\mathrm{cm^2}$$



t = thickness of deck plating in mm a ≥ 150 + 60pK mm

Fig. D 24.5

2482 Ice stringers combined with web frames are to comply with 2481, except that:—

S = distance, in mm, between web frames, and the product p K is not to be taken less than 5 kg/cm².

The ice framing is to be attached by brackets or similar to the stringer. The distance, r, between brackets, in mm, is to be chosen so that p K \leq 4800 $\frac{t^3}{r^2}$ kg/cm². See Fig. D 24.6.

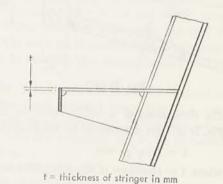


Fig. D 24.6

The section modulus of web frames supporting ice stringers or longitudinal frames is determined by the formula:—

$$\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{p}\; \mathrm{K}\; \mathrm{S}\; Z}{12.5\; f_{\mathrm{y}}}\; \mathrm{cm}^{\mathrm{s}}$$

where K is as defined in 2481,

p and fy are as defined in 2462,

Z = span of web frame, in mm,

p K is not to be taken less than 5 kg/cm².

The required shear area of the web frame supporting one stringer is determined by 2481. For a web frame supporting several ice stringers or longitudinal frames, the shear area, determined by 2481 should be increased by 50 per cent.

Where ice stringers are fitted, the span, *I*, in 2462 for determining main and intermediate frames may be taken as the distance between ice stringers or between stringer and deck.

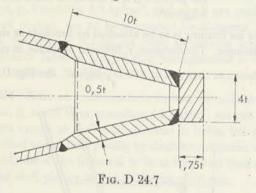
Stem

2483 The stem is to be made of rolled, cast or forged steel, or of shaped steel plates. A sharp edged stem (as in Fig. D 24.7) improves the ability to cut into ice, in particular when the length of the ship is less than 150 m.

2484 The section modulus in the fore and aft direction is not to be less than:—

$$\frac{I}{y} = 22\sqrt{p^3} \text{ cm}^3$$

where p = the pressure as determined by 2461—forward region.



(a) The dimensions of a welded stem as shown in Fig. D 24.7 are determined by the formula:—

$$t = 7.6 \sqrt{p}$$
 mm

where t = thickness of the side plates and

p = the pressure as determined by 2461 forward region. The reinforced stem is to be extended from the keelplate up to 750 mm above the load waterline and is to be internally strengthened by floors, brackets or webs having a thickness of at least t/2 mm and spaced not more than 600 mm apart.

(b) The plate thickness, t, of a shaped plate stem or a bulbous bow is determined by the formula:—

$$t = \frac{4\,\text{s}}{5} \sqrt{\frac{\text{p}_4}{\text{fy}}} + 2\;\text{mm}$$

where $p_4 = 1.4 p$ for the forward region.

s = the distance, in mm, between horizontal webs or diaphragm plates, having a thickness of at least t/2 mm.

fy is as defined in 2462.

Where in the ice belt region the curvature of the stem or bulb front plating is large, one or several vertical stiffener(s) is(are) to be fitted in order to meet the section modulus requirement.

- (c) The dimensions of the stem may be tapered to the requirements of D 12 at the upper deck.
- (d) The connections of the shell plating to the stem are to be flush.

2485 A mooring pipe with an opening not less than 250 by 300 mm and a rounding radius not less than 100 mm of inner surfaces at least 150 mm wide is to be fitted in the centreline of the bow bulwark, for towing purposes. A bitt or other convenient means of securing the line is to be dimensioned to withstand the Rule breaking strength of the ship's towline.

2486 Strengthening of the bow plating and framing in an area 2 to 3 m from the stem abaft and 4 to 5 m in height above the LWL is recommended, to take account of the stresses occuring when the ship is in short tow in the icebreaker's stern fork.

Ships, the bulbous bows of which extend more than 2 m forward of the forward perpendicular, cannot be taken in short tow by existing Finnish-Swedish icebreakers.

Stern Frames

2487 Where the screw shaft diameter exceeds the Rule diameter, the propeller post is to be correspondingly strengthened. See D 1215.

Bossings and Shaft Struts

2488 Shaftings and stern tubes of ships with two or more propellers are to be enclosed within plated bossings. If detached supporting struts are absolutely unavoidable, their design, strengthening and attachment to the hull are to be duly considered.

Rudder and Steering Arrangements

2489 The rudder post, solepiece, rudder head, pintles, etc., are to be dimensioned in accordance with D 12, D 22 and D 23. However, the speed used in the calculations is in no case to be taken less than:—

IA Super 20 knots

IA 18 knots

IB 16 knots

IC 14 knots

If the actual maximum service speed of the ship is higher than the above values, the higher speed is to be used in the calculations, and no extra strengthening is required.

2490 For double plate rudders, the minimum thickness of plates and horizontal and vertical webs in the ice belt region is to be determined as for shell plating in the aft region in accordance with 2477.

2491 The rudder head and the upper edge of the rudder are to be protected against ice pressure by an ice knife or equivalent means, for the Ice Classes IA Super and IA.

2492 Efficient rudder stops, a slip coupling or equivalent arrangements are to be fitted in order to protect the steering gear against excessive external loading.

Section 25

DECK LOADING

Permissible Cargo Loading on Decks and Hatch Covers having Minimum Rule Scantlings

Weather Decks

2501 That equivalent to a 1,2 m (4 ft) head with a stowage rate of 1,39 m³/tonne (50 ft³/ton) i.e., 0,87 tonne/ $m^2(0.08 \text{ ton/ft}^2)$.

Cargo Decks

2502 That equivalent to a head equal to the 'tween deck height (h metres (feet)) with a stowage rate of 1,39 m³/tonne (50 ft³/ton) i.e., 0,72h tonne/m² (0·02h ton/ft²). See also 2504.

Hatch Covers

2503 For hatch covers fitted on weather decks in positions 1 and 2 (see D 2605), the maximum cargo load is that equivalent to a head of 1,5 m (5 ft) and 1,2 m (4ft) respectively, with a stowage rate of 1,39 m³/tonne (50 ft³/ton), unless the supporting deck girders and pillars are increased in size, in which case, see 2509 and 2510.

Lower Decks forming Crown of Deep or Tunnel Tanks

- 2504 That equivalent to the greater of the following:-
 - (a) A head equal to the 'tween deck height with a stowage rate of 1,39 m³/tonne (50ft³/ton),
 - (b) A head equal to one-half the height of the air pipe above the tank crown with a stowage rate of 0,975 m³/tonne (35 ft³/ton).

Inner Bottom

2505 For ships having the class 100A1 the loading on the tank top may be that equivalent to a head of 1,4d with a stowage rate of 1,39 m³/tonne (50 ft³/ton). d is the load draught, in metres (feet).

For ships having Heavy Cargo or Ore Cargo notations the inner bottom may be suitable for increased loads—see D 609 and D 610.

Specified Cargo Loading on Decks and Hatch Covers in excess of that given in 2501 to 2504

2506 If the actual loading is in excess of the nominal Rule loading, then the appropriate h values, with the exceptions given in 2507, 2508, 2509 and 2510, are to be increased in direct proportion.

2507 For weather deck hatch side coamings, hatch end beams, girders and pillars, the head h to be used is 1,39 p m (50 p ft), plus an allowance for weather as follows:—

- (i) when the basic h as obtained from D 6 or D 8 is 1,2 m (4 ft) or less——nil.
- (ii) when h obtained from D 6 or D 8 is 1,5 m (5 ft)——0,3 m (1 ft).

(Intermediate values are to be in proportion.)

 $p = \text{actual deck loading in tonne/m}^2 (\text{ton/ft}^2).$

2508 For deck longitudinals and beams, the scantlings are to be obtained from D 604 and D 809, using the head obtained from 2506 for cargo decks and 2507 for weather decks. The modulus of weather deck longitudinals or beams is not to be less than that obtained from D 602 and D 806.

2509 Hatch covers in position I need not be increased where the head obtained from 2506 (i.e., without any addition for weather) is 2,44 m (8 ft) or less; when it exceeds 2,44 m (8ft) the scantlings are to be increased in direct proportion.

2510 Hatch covers in position 2 need not be increased where the head obtained from 2506 (i.e., without any

addition for weather) is 1.8 m (5.9 ft) or less; when it exceeds 1.8 m (5.9 ft) the scantlings are to be increased in direct proportion.

2511 Where heavy loads are to be carried, the side framing in way may require to be strengthened.

Concentrated Loads

2512 Where provision is required for concentrated loads, then scantlings and arrangements will be considered.

See D 418 for fork lift trucks.

Hanging Cargoes

2513 See D 603, D 605, D 807 and D 810.

Fruit or similar Light Cargoes

2514 Where the deck is designed for the carriage of fruit or similar light cargoes only, the head used for the calculations can be reduced in a similar manner to that given in 2506 but is not to be taken as less than 1,2 m (4 ft).

Section 26

HATCHWAYS AND DECK OPENINGS

Note. Where relevant, the contents of this Section conform with the requirements of the 1966 Load Line Convention.

Definitions

2601 L = length of ship, in metres (feet).

h = head, in metres (feet), and is to be taken as follows:—

For position 1

$$h = 1.07 + \frac{L}{72.5} \text{ m} \left(h = 3.5 + \frac{L}{72.5} \text{ ft} \right)$$

but need not exceed 2.45 m (8 ft).

For position 2

$$h = 0.8 + \frac{L}{100} \text{ m} \left(h = 2.62 + \frac{L}{100} \text{ ft} \right)$$
but need not exceed 1.8 m (5.9 ft).

For definitions of positions 1 and 2—see 2605.

The above heads apply in conjunction with a stowage rate of 1,39 m³/tonne (50 ft³/ton).

In 'tween decks,

h = 'tween deck height, in metres (feet), measured vertically on the centreline of the ship from deck to deck.

Provided the stowage rate does not exceed 1,39 m³/tonne (50 ft³/ton), hatch coamings above not exceeding 1 m (3·28 ft) in height may be ignored.

For specified rates of loading in excess of 1,39 m³/tonne (50 ft³/ton), or where the hatch coamings above exceed 1 m (3·28 ft) in height, then an equivalent h is to be used. See also D 25.

The following definitions apply to webs or stiffeners with attached plating, or portable beams:—

\$l_o\$ = unsupported span, in metres (feet), measured as shown in Fig. D 26.1,

\$\lambda_1\$ = proportion of the span, in metres (feet), measured as shown in Fig. D 26.1. The depth and face area over the remainder of the span is assumed to be constant.

s = spacing, in mm (in),

d = overall depth at the supports, measured as shown in Fig. D 26.1, but is not to be less than 150 mm (6 in)—see also definition of I₁.

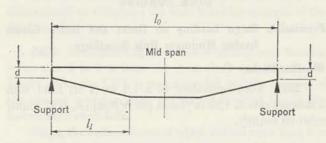


Fig. D 26.1—Diagrammatic Profile of Web or Stiffener or Portable Beam

$$\alpha = \frac{l_1}{l_0}$$

$$\left(\frac{I}{y}\right)_0 = \text{section modulus, in cm}^3 \text{ (in}^3\text{), at midspan.}$$

$$\left(\frac{I}{y}\right)_1 = \text{section modulus, in cm}^3 \text{(in}^3\text{), at supports.}$$

$$\gamma = \frac{\left(\frac{I}{y}\right)_1}{\left(\frac{I}{y}\right)_0}$$

$$\mathsf{K} = 1 + \frac{3.2\,\alpha - \gamma - 0.8}{7\,\gamma + 0.4} \left\{ \begin{array}{l} \text{To be specially considered when discontinuities in area of face material occur.} \end{array} \right.$$

I_o = moment of inertia, in cm⁴ (in⁴), at midspan.

 I_1 = moment of inertia, in cm⁴ (in⁴), at supports, and is not to be less than 0,05 I_0 .

$$\beta = \frac{I_{i}}{I_{o}}$$

$$C = 1 + \frac{8 \,\alpha^3 \,(1-\beta)}{0.2 + 3 \,\sqrt{\beta}} \, \begin{cases} & \text{To be specially considered when discontinuities in area of face material occur.} \end{cases}$$

Application

2602 The scantlings given in this Section apply basically to rectangular covers with the stiffening members arranged primarily in one direction, and carrying a uniformly distributed load. Where covers have members arranged in a grillage formation, and/or point loads are applied, the scantlings of the covers will be specially considered.

Other Materials

2603 The scantlings given in this Section are applicable to mild steel. Where other materials, such as aluminium are to be used, equivalent scantlings are to be provided.

WEATHER DECK HATCHWAYS

2604 For the purposes of this Section, four basic types of ship are defined:—

B-100 cargo ships with tanker freeboard,

B-60 cargo ships with intermediate freeboard,

B cargo ships with "Type B" freeboard,

B+ cargo ships with increased freeboard.

Position of Hatchways

2605 Position 1 hatchways on exposed freeboard and raised quarter decks, and exposed superstructure decks within the forward 0.25L.

Position 2 hatchways on exposed superstructure decks abaft the forward 0,25L. Steel Covers Fitted with Direct Securing Arrangements for "B-100", "B-60" or "B" Type Ships

2606 These are plated covers stiffened by webs or stiffeners, weathertightness being obtained by gaskets and clamping devices.

The section modulus and moment of inertia of the webs or stiffeners are to satisfy the following formulæ respectively:—

$$\frac{\text{(i)}}{107.5} \frac{\text{hs} \, l_{\,\text{o}}^{\,2} \, \text{K}}{\left(\frac{\text{I}}{\text{y}} \right)_{\,\text{o}}} \leqslant 1 \quad \left(\frac{\text{hs} \, l_{\,\text{o}}^{\,2} \, \text{K}}{2450 \, \left(\frac{\text{I}}{\text{y}} \right)_{\,\text{o}}} \leqslant 1 \, \text{British} \right)$$

$$\frac{\text{(ii)} \quad \mathsf{hs}\, l_{\,\mathsf{o}}{}^{\mathsf{3}}\; \mathsf{C}}{63.7\; \mathsf{I}_{\,\mathsf{o}}} \leqslant 1 \qquad \left(\frac{\,\mathsf{hs}\, l_{\,\mathsf{o}}{}^{\mathsf{3}}\; \mathsf{C}}{12\; 100\; \mathsf{I}_{\,\mathsf{o}}} \right. \leqslant 1 \;\; \mathsf{British}\right)$$

The thickness of plating is not to be less than:-

 $t = \frac{s}{100}$ mm (in) or 6 mm (0·24 in), whichever is the greater.

Where h exceeds 3,5 m (11.5 ft) the above thicknesses are to be increased by the factor

$$\sqrt[3]{\frac{h}{3,5}}$$
 $\left(\sqrt[3]{\frac{h}{11 \cdot 5}}\right)$ British.

2607 Securing cleats and cross joint wedges, together with suitable jointing material, are to be fitted to secure the weathertightness of the covers to the satisfaction of the Surveyors. The arrangements shall ensure that the tightness can be maintained in any sea conditions, and for this purpose tests for tightness shall be required at the initial survey, and may be required at periodic surveys and at annual inspections or at more frequent intervals.

The spacing of securing cleats on hatches is to be as follows:—

Hatch sides—cleats are to be spaced about 2 m (6 · 6 ft)
apart with generally a minimum of 2
cleats per panel. Where hydraulic or
mechanical means of securing are employed
one securing device per panel will be
considered assuming arrangements are
provided for inter-locking the panels.

Hatch ends—cleats are to be spaced about 2 m (6.6 ft) apart with one arranged adjacent to each corner.

Cross-joint wedges to be spaced about 1,5 m (4.9 ft) apart. Alternatively, where positive securing devices are arranged on the lower side of the joint to ensure continuing compression of the joint, these can be accepted about 3 m (9.8 ft) apart.

Steel hatch covers with special sealing arrangements or insulated covers will be specially considered. 2608 Where it is proposed to omit coamings on weather decks, the strength and closing arrangements of the hatch covers will be specially considered.

2609 Where hatch covers are fitted to holds used as tanks the strength, stiffness, sealing and securing arrangements will be specially considered.

Steel Pontoon Covers-For "B" Type Ships Only

2610 These are plated covers having interior webs and stiffeners, extending for the full width of the hatchway and about one quarter of the length, and not fitted with direct securing arrangements.

The section modulus and moment of inertia of the webs or stiffeners are to satisfy the following formulæ respectively:—

(i)
$$\frac{\operatorname{hs} l_{o}^{2} K}{91,3 \left(\frac{I}{y}\right)_{o}} \leqslant 1 \qquad \left(\frac{\operatorname{hs} l_{o}^{2} K}{2080 \left(\frac{I}{y}\right)_{o}} \leqslant 1 \quad \operatorname{British}\right)$$

(ii)
$$\frac{\mathsf{hs}\,l_{\mathsf{o}}^{\,3}\,\mathsf{C}}{\mathsf{50}\,\mathrm{I}_{\mathsf{o}}}\leqslant 1 \qquad \left(\frac{\mathsf{hs}\,l_{\mathsf{o}}^{\,3}\,\mathsf{C}}{9500\,\mathrm{I}_{\mathsf{o}}}\leqslant 1 \quad \mathsf{British}\right)$$

The plating thickness is to be as required by 2606.

2611 The requirements of 2621 to 2625 are to be complied with.

Paragraphs 2612 to 2625 refer to hatch covers used in conjunction with portable beams, and not using direct securing arrangements, and may be fitted on "B+" ships only.

Wood Covers

2612 Wood covers at positions 1 and 2 are to have a thickness not less than 60 mm ($2\frac{3}{8}$ in) in association with an unsupported span of 1,5 m ($4\cdot9$ ft) and 82 mm ($3\frac{1}{4}$ in) with 2 m ($6\cdot56$ ft); the thicknesses for intermediate spans are to be in proportion.

2613 The ends of all wood hatch covers are to be protected by encircling galvanized steel bands about 65 mm (2.5 in) wide and 3 mm ($\frac{1}{8}$ in) thick, efficiently secured.

Portable Steel Covers

2614 The section modulus and moment of inertia of stiffeners is to be in accordance with 2606. The thickness of plating is not to be less than:—

$$t = \frac{s}{100}$$
 mm (in) or 3.5 mm (0.14 in)

whichever is the greater,

Hatch Rests

2615 Hatch rests are to provide at least 65 mm (2.5 in) bearing surface and are to be bevelled if required to suit the slope of the hatches.

Portable Hatch Beams

2616 The section modulus and moment of inertia of portable web plate beams stiffened at their upper and lower edges by continuous flat bars are to satisfy the following formulæ respectively:—

(i)
$$\frac{\text{hs } l_o^2 \text{ K}}{91.3 \left(\frac{\text{I}}{\text{y}}\right)_o} \leqslant 1$$
 $\left(\frac{\text{hs } l_o^2 \text{K}}{2080 \left(\frac{\text{I}}{\text{y}}\right)_o} \leqslant 1 \text{ British}\right)$

(ii)
$$\frac{\text{hs } l_o^3 \text{C}}{50 \text{ I}_o} \leqslant 1$$
 $\left(\frac{\text{hs } l_o^3 \text{C}}{9500 \text{ I}_o} \leqslant 1 \text{ British}\right)$

2617 The ends of web plates are to be doubled or inserts fitted at least 180 mm (7 in) wide.

2618 At beams which carry the ends of wood or steel hatch covers a vertical 50 mm (2 in) flat is to be arranged on the upper face plate and the bearing surface for hatch covers is not to be less than 65 mm (2.5 in).

2619 Portable beams are to be supported at their ends by carriers, sockets or other suitable arrangements, having a minimum bearing surface of 75 mm (3 in).

2620 Sliding hatch beams are to be provided with an efficient device for locking them in their correct fore and aft positions when hatchway is closed.

Tarpaulins and Securing Arrangements

2621 At least two layers of tarpaulin in good condition shall be provided for each hatchway in positions 1 or 2.

2622 Tarpaulins are to be free from jute, thoroughly waterproofed and of ample strength. The minimum weight of the material before treatment is to be 0,65 kg/m² (19 oz/yd²) if the material is to be tarred, 0,60 kg/m² (18 oz/yd²) if to be chemically dressed, or 0,55 kg/m² (16 oz/yd²) if to be dressed with black oil.

A certificate to the above effect is to be supplied by the makers of the tarpaulins.

Special consideration will be given when covers of synthetic material are proposed in lieu of tarpaulins.

2623 Cleats are to be of an approved pattern at least 65 mm (2·5 in) wide, with edges so rounded as to minimize the cutting of the wedges, and shall be spaced not more than 600 mm (23·5 in) from centre to centre; the cleats

along each side or end are to be arranged not more than 150 mm (6 in) from the hatch corners.

The thickness should not be less than 9,5 mm ($\frac{3}{8}$ in) for angle cleats, and 11 mm ($\frac{7}{16}$ in) for smithed cleats which should be stiffened by pressing out the centre to form a web extending to the bottom of the palm. Drop forgings should be of equivalent strength. Cleats should be so set as to fit the taper of the wedges.

2624 Battens and wedges shall be efficient and in good condition. Wedges are to be of tough wood, generally not less than 200 mm (8 in) in length and 50 mm (2 in) in width. They should have a taper of not more than 1 in 6 and should not be less than 13 mm (0.5 in) at the point.

2625 For all hatchways in positions 1 and 2, steel bars or other equivalent means shall be provided in order efficiently and independently to secure each section of hatch covers after the tarpaulins are battened down.

Hatch covers of more than 1,5 m (4.9 ft) in length are to be secured by at least two such securing appliances. Where hatchway covers extend over intermediate supports, steel bars or their equivalent are to be fitted at each end of each section of covers. At all other hatchways in exposed positions on weather decks ring bolts or other fittings for lashings are to be provided.

Hatchway Coamings

2626 The height of coamings above the upper surface of the deck, measured above sheathing if fitted, for hatchways closed by portable covers secured weathertight by tarpaulins and battening devices is not to be less than:—

Position 1 600 mm (23.5 in)

Position 2 450 mm (17.5 in)

The height of coamings of hatchways situated in positions 1 or 2 and closed by steel covers fitted with direct securing arrangements are to be as specified above, but may be reduced or the coamings omitted entirely if the safety of the ship is not impaired in any sea conditions.

In the case of flush hatch covers or those having coamings less than stated in this paragraph the scantlings and securing arrangements will be specially considered.

2627 Hatchways on other decks and in positions not detailed in 2626 are to be suitably framed.

Construction of Weather Deck Coamings

2628 The thickness of hatch coamings is not to be less than 11 mm (0.43 in).

2629 Coamings 600 mm (23.5 in) or more in height are to be stiffened on their upper edges by a horizontal

bulb flat or equivalent not less than 180 mm (7 in) in depth. Additional support is to be afforded by fitting brackets or stays from the bulb flat to the deck at intervals of not more than 3 m (9.84 ft).

Coamings less than 600 mm (23.5 in) in height are to be stiffened on their upper edges by a substantial moulding.

2630 The scantlings and arrangements of coamings more than 900 mm (35.5 in) in height and of coamings acting as girders will be specially considered.

2631 Side coamings of all hatchways are to extend at least to the lower edge of the deck beams which are to be effectively attached to the coamings as required by Table D 32.1.

2632 Extension brackets or rails arranged approximately in line with the hatch side coamings and intended for stowage of steel covers are not to be welded to a deckhouse, masthouse, or to each other, unless they form part of the longitudinal strength members.

2633 For details of arrangement of coamings at hatch corners, see D 419.

HATCHWAYS IN CARGO OR ACCOMMODATION SPACES

2634 In cargo spaces, steel hatch covers (including pontoon covers) and portable hatch beams are to have scantlings and arrangements as required by 2606, but modified as follows:—

- (a) The section modulus may be 6 per cent less than given by 2606 (i).
- (b) The inertia requirements may be 20 per cent less than given by 2606 (ii).

2635 In accommodation spaces, the 'tween deck height (h) is to be taken as 1,8 m (5.9 ft).

2636 Wood covers are to have a thickness not less than 60 mm ($2\frac{3}{8}$ in) in association with an unsupported span of 1,5 m ($4\cdot9$ ft) and 82 mm ($3\frac{1}{4}$ in) with 2 m ($6\cdot56$ ft); the thicknesses for intermediate spans are to be in proportion.

When the 'tween deck height (h) exceeds 2,6 m (8.5 ft) the thickness of the covers is to be increased at the rate of 16,5 per cent per metre (5 per cent per foot) excess in 'tween deck height.

For details of wood covers, see 2613.

TABLE D 26.1

Fork Lift Trucks

2637 Where fork lift trucks are to be used the thickness of the hatch cover plating is to be in accordance with D 418 and the modulus of the stiffeners is to be not less than:—

$$\frac{I}{y} = F_1 T l + \frac{F_2 h l^2 s}{600} cm^3 (in^3)$$

but neither is to be less than required by 2634. F_1 and F_2 are coefficients obtained from Table D 26.1, and T = total weight of truck and its load in tonnes (tons).

Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of stiffeners may be approved on the basis of grillage type calculation.

Tank Hatch Covers in 'Tween Decks

2638 The scantlings of steel tank hatch covers situated in 'tween decks are to be determined as for cargo deck hatch covers but the scantlings must in no case be less than would be required by D 19 for a deep tank bulkhead.

The maximum spacing of cleats and cross-joint wedges is to be 600 mm (23.5 in), but cleats are to be arranged as close as practicable to the corners.

GENERAL

Bunker, Access and Trimming Hatchways

2639 The construction and the closing and securing arrangements of bunker, access and trimming hatchways are to comply with the requirements of 2601 to 2633 so far as applicable.

Manholes and Flush Scuttles

2640 Manholes and flush scuttles fitted in positions 1 or 2 or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers shall be permanently attached.

Trunked Hatchways

2641 When hatchways are trunked through one or more 'tween decks, and hatchway beams and covers are dispensed with at the intermediate decks, the hatchway beams, coamings and covers immediately below the trunk are to be adequately strengthened; plans are to be submitted for approval.

Means of Escape

2642 In and from all crew and passenger spaces and spaces in which crew are normally employed, other than

Distance between load-bearing wheels Stiffener span	F ₁	F ₂
0,1	11,96 (0·226)	2,32 (0·102)
0,2	10,69 (0·202)	1,89 (0·083)
0,3	9,58 (0·181)	1,55 (0·068)
0,4	8,46 (0·160)	1,28 (0·056)
0,5	7,46 (0·141)	1,07 (0·047)
0,6	6,51 (0·123)	0,91 (0·040)
0,7	5,55 (0·105)	0,73 (0·032)
0,8	4,23 (0·080)	0,36 (0·016)
0,9	2,38 (0·045)	0,11 (0·005)

machinery spaces, stairways and ladders are to be arranged so as to provide ready means of escape to the lifeboat embarkation deck. (For means of escape from machinery spaces, see D 2113.)

Companionways

2643 Companionways on exposed decks are to be of steel effectively secured to the deck. The height, measured above sheathing if fitted, of the doorway sills in companionways is not to be less than 600 mm (23.5 in) in position 1 and 380 mm (15 in) in position 2, see 2605.

2644 The doors in positions 1 and 2—see 2605—are to be made of steel or equivalent material, and are to be secured weathertight by gaskets and clamping devices or equivalent means.

Elsewhere, doors may be of hardwood not less than 50 mm (2 in) in thickness.

All doors are to be capable of being operated and secured from both sides.

Cross-reference

2645 For welding requirements, see Table D 32.1.

MASTS AND RIGGING

2701 The scantlings of steel masts and derrick posts intended to support derrick booms of 15 tonnes (tons) S.W.L. and under are to be determined from the greatest stresses expected to arise when the cargo gear is correctly used. The scantlings of masts and derrick posts supporting one or more derrick booms with a S.W.L. exceeding 15 tonnes (tons) and those of bipod or other special designs including stayed masts where the stays are attached to the outer end of crosstrees will be considered in accordance with the Society's Code of Practice for the Construction and Survey of Ship's Cargo Handling Gear.

Mild steel used for masts, derrick posts, etc., and their associated crosstrees and brackets is to be of D quality if the thickness exceeds 20,5 mm (0.80 in).

2702 A stayed mast or derrick post is one that is supported by one or more stays. A "stay" includes shrouds, forestays, backstays, etc.

Calculations-General

2703 The derrick or derricks are to be assumed to be initially at an angle of 30° to the horizontal or at the minimum angle specified (by the owner or builder) if this is less than 30°, the angles being measured when the ship is upright and without trim, but for calculations made with derricks swung outboard the effect of heel is to be taken into account if the heel of the ship is likely to exceed 5° with the derrick booms in this position and whilst working as swinging derricks carrying the full S.W.L.

Stayed Masts and Posts

2704 The scantlings of stayed masts and stayed derrick posts are generally to be obtained from Table D 27.1 and the required size of their associated stays are to be obtained from Tables D 27.1, D 27.2 and D 27.3 by the method given in 2705 to 2711.

Where two sets of derricks with horizontal span tackle pull resultants which vary by more than 20 per cent of the higher value are fitted to the same mast, then, if the mast is a stayed mast, a full stress calculation must be submitted—see Note to Table D 27.1.

2705 Calculations should normally be submitted for the following conditions:—

- (a) For masts with four derricks:-
 - (i) with two derricks plumbing one hatch;
 - (ii) with two derricks swung to their most outboard working position on one side of the ship.

- (b) For masts with one derrick fitted forward and one aft:—
 - (i) with one derrick at its greatest working outreach in a fore and aft direction;
 - (ii) with both derricks swung to their most outboard working position on one side of the ship.

In each case the above derricks are to be considered as swinging derricks carrying the full S.W.L.

If other arrangements seem likely to give stresses significantly larger than either of the above, then a calculation is to be made for this "worst" configuration in addition to the others.

2706 The "Resultant of horizontal pulls of span tackles" is to be the resultant of the horizontal pulls of the span tackles of the derricks under load, plus any cargo runners that may be led to the mast head.

2707 The lengths of masts and posts are to be measured from the uppermost deck through which they pass to the mean intersection of the span and stay lines of action. (For this purpose, where a mast or post is supported by a deckhouse, the house top is to be regarded as a deck unless the house is specifically designed to give no effective support to the mast or post in both the transverse and fore and aft directions.)

Mast Scantlings

2708 The diameter and thickness of the mast or post at deck level is to be derived from Table D 27.1 for the appropriate resultant pull of span tackles and mast length. The diameter and thickness of the mast or post at the hounds are assumed to be 85 per cent of the Table values.

Stay Sizes

2709 Stay sizes are to be determined by means of two factors; "B" and "C".

Factor B is to be obtained from Table D 27.1 for the appropriate mast length and resultant pull of span tackles.

Factor C is to be obtained from Table D 27.2.

In Table D 27.2 the symbols are as follows:—

h is the horizontal spacing of the mast-head stay eyeplate and the deck (or bulwark) stay eyeplate. h may vary for each stay (see Fig. D 27.1 where varying values of h are shown as h_1 , h_2 , h_3 and h_4).

x is the horizontal distance from the deck (or bulwark) stay eyeplate to the line of action of the derrick boom

(or mean line of action of the derrick booms if more than one will be in use). x may vary for each stay see Fig. D 27.1.

In Fig. D 27.1 the derrick boom is shown hung on the mast. Where a boom is hung on a crosstree of normal length, the "line of action" of the boom should be transferred to the centre of the mast before measuring x and h values.

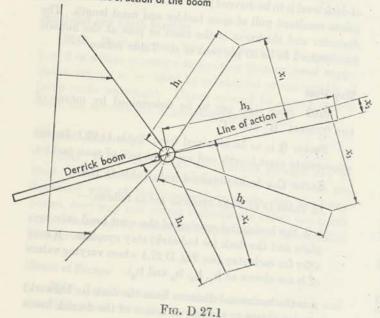
If the mast's stays are attached to a point a short way along a crosstree (see 2718), the line of action of the stays should be transferred to the centre of the mast before measuring x and h.

Where the stays are attached to the end of crosstrees or where derrick span blocks are attached to crosstrees at a much greater than normal distance from the mast, then a full stress calculation will be necessary.

V is the vertical spacing of the mast-head stay eyeplate and the deck (or bulwark) stay eyeplate. V may vary for each stay due to variations in deck or bulwark levels, but Table D 27.1 is only applicable if the stays are attached to the mast at or near to the same level as the span tackle.

The values of $\frac{x}{h}$ and $\frac{h}{v}$ are to be used to obtain the appropriate value of factor C for each stay.

These stays are not included in the calculation for this boom position as they make angles greater than 90° to the line of action of the boom



2710 The values of factor C for all stays are to be added and the required metallic cross-sectional area of each stay is to be obtained from the following formula:—

$$\begin{array}{l} {\rm Area} = 645 \; {\rm A_W} = 645 \; \frac{{\rm Factor} \; {\rm B}}{{\rm Sum} \; {\rm of} \; {\rm Factors} \; {\rm C}} \end{array}$$

or in British units:

$${\rm Area} = A_W = \frac{\cdot \ Factor \ B}{{\rm Sum \ of \ Factors \ C}} \ {\rm in^2}$$

This formula assumes that all stays are the same size and construction and that the heights v in no case exceed the mast length by more than 1.25 m (4.1 ft).

If v, for any particular stay, does exceed the mast length by more than 1,25 m (4·1 ft) then the metallic cross-sectional area for that particular stay is to be increased in the ratio of v

2711 The size of stays equivalent to various values of $A_{\rm W}$ are given in Table D 27.3 for representative wire ropes, but exact values provided by the manufacturer of any particular rope are acceptable.

Stress Calculations-Unstayed Masts and Posts

2712 Where only one derrick is to be loaded at one time (e.g., a heavy derrick on the ship's centreline), or where two derricks may be loaded at the same time but while working different hatches, the worst stresses, for rigs of normal design, can be assumed to occur with the derrick boom or booms swung outboard (on the same side of the ship if two booms are concerned).

Where two derricks are designed to work one hatch simultaneously, the worst stresses, for masts of circular section, can be assumed to occur with both booms plumbing that hatch.

2713 The reaction of a derrick heel is to be ignored when calculating the bending moment in a mast or post, unless the gooseneck, trunnion or other similar heel fitting is attached to the mast or post, or to a lower crosstree or outrigger, which is wholly supported by the mast or post.

2714 The bending moment acting at any particular point is the sum of:—

(a) Each force component acting perpendicularly to the mast or post, and parallel to the plane in which the mast or post will bend, multiplied by the distance (measured parallel to the mast or post) of that force above the point under consideration.

TABLE D 27.1-MAST SCANTLINGS AND FACTOR "B"

Mast			TOTAL RES	ULTANT OF H	ORIZONTAL PU	ULLS OF SPAN	TACKLES	
LENGTH		No Load	5 TONNES (TONS)	10 TONNES (TONS)	15 tonnes (tons)	20 TONNES TONS	25 TONNES (TONS)	30 TONNES (TONS)
metres (feet) 9,25 (30′ 4″)	Mast size Factor B	$\begin{array}{c} \text{mm} \\ \text{(in)} \\ 300 \times 6 \\ (11\frac{3}{4} \times 0.24) \\ 0,030 \end{array}$	mm (in) 460×7,5 (18‡×0·30) 0,112	mm (in) 510×9 (20½×0·35) 0,265	$\begin{array}{c} \text{mm} \\ \text{(in)} \\ 570 \times 12 \\ (22\frac{3}{8} \times 0.47) \\ 0,439 \end{array}$	$\begin{array}{c} \text{mm} \\ \text{(in)} \\ 630 \times 12,5 \\ (24\frac{3}{4} \times 0 \cdot 49) \\ 0,680 \end{array}$	$\begin{array}{c} \text{mm} \\ \text{(in)} \\ 700 \times 12,5 \\ (27\frac{1}{2} \times 0.49) \\ 0,939 \end{array}$	$\begin{array}{c} \text{mm} \\ \text{(in)} \\ 760 \times 12.5 \\ (29\frac{2}{8} \times 0.49) \\ 1,246 \end{array}$
10,75 (35′ 3″)	Mast size Factor B	$\begin{array}{c} 360 \times 6,5 \\ (14\frac{1}{8} \times 0.26) \\ 0,030 \end{array}$	510×8 (20½×0·31) 0,101	$\begin{array}{c} 570 \times 10 \\ (22\frac{1}{2} \times 0.39) \\ 0.243 \end{array}$	$\begin{array}{c} 630 \times 11,5 \\ (24\frac{3}{4} \times 0.45) \\ 0,430 \end{array}$	$700 \times 12 \atop (27\frac{5}{8} \times 0.47) \atop 0,639$	$\begin{array}{c} 760 \times 12 \\ (29 \% \times 0.47) \\ 0.885 \end{array}$	810×13 (317×0·51) 1,137
12,25 (40' 2")	Mast size Factor B	$\begin{array}{c} 410 \times 7 \\ (16\frac{1}{8} \times 0.28) \\ 0,030 \end{array}$	$560 \times 7,5 \\ (22 \times 0.30) \\ 0,093$	$\begin{array}{c} 620 \times 10,5 \\ (24\frac{3}{8} \times 0.41) \\ 0,230 \end{array}$	670×12 (263×0·47) 0,394	$\begin{array}{c} 740 \times 12,5 \\ (29 \frac{1}{8} \times 0.49) \\ 0,591 \end{array}$	$790 \times 13,5$ $(31\frac{1}{8} \times 0.53)$ 0,799	840×14 (33×0·55) 1,018
13,75 (45′ 1″)	Mast size Factor B	460×7,5 (18½×0·30) 0,030	580×8 $(22\frac{3}{4} \times 0 \cdot 32)$ $0,082$	650×10,5 (25§×0·41) 0,217	710×12 (28×0·47) 0,368	$760 \times 13 \\ (29\frac{7}{8} \times 0.51) \\ 0,538$	810×14 (31½×0·55) 0,730	860×14,5 (33½×0·57) 0,927
15,25 (50′ 0″)	Mast size Factor B	510×8 (20½×0·31) 0,030	$\begin{array}{c} 610 \times 9.5 \\ (24 \times 0.37) \\ 0.072 \end{array}$	$\begin{array}{c} 690 \times 11 \\ (27\frac{1}{8} \times 0.43) \\ 0,202 \end{array}$	$\begin{array}{c} 740 \times 13 \\ (19 \frac{1}{8} \times 0.51) \\ 0,338 \end{array}$	790×14 (31½×0·55) 0,497	840×14,5 (33×0·57) 0,674	900×15,5 (35 §×0·61 0,854
16,75 (54' 11")	Mast size Factor B	$560 \times 8,5$ (22×0.34) 0,030	$\begin{array}{c} 660 \times 9,5 \\ (26 \times 0.37) \\ 0,068 \end{array}$	$\begin{array}{c} 720 \times 11 \\ (28\frac{1}{8} \times 0.43) \\ 0{,}190 \end{array}$	$\begin{array}{c} 790 \times 12,5 \\ (31\frac{1}{8} \times 0.49) \\ 0,328 \end{array}$	840×14 (33×0·55) 0,478	$\begin{array}{c} 890 \times 14,5 \\ (35 \times 0.57) \\ 0,648 \end{array}$	940×15,5 (37×0·61) 0,824
18,25 (59' 10")	Mast size Factor B	610×9 (24×0·35) 0,030	710×10 (28×0·39) 0,059	760×11 $(29\frac{7}{8} \times 0.43)$ $0,180$	$\begin{array}{c} 810 \times 13,5 \\ (31\frac{7}{8} \times 0.53) \\ 0,304 \end{array}$	$\begin{array}{c} 860 \times 15 \\ (33\frac{7}{8} \times 0.59) \\ 0,443 \end{array}$	$910 \times 15,5 \ (35\frac{7}{8} \times 0.61) \ 0,600$	970×16 (38½×0·63 0,774

Note.—When two sets of derricks with differing span tackle pulls are hung one forward and one aft of a mast, it will be possible to use Table D 27.1 only if the difference in the span pull resultants does not exceed 20 per cent of the larger pull. Within these limits the mast size chosen should be the smaller of the differing scantlings derived from the Table, but the values of factor B should be those appropriate to the span resultant in each case. Where the span resultants vary by more than 20 per cent, a full stress calculation should be made (see 2701).

Excessively stiff masts, i.e., masts in which the inertia is greater than that shown in the Table, should not be fitted since they will deflect less than assumed and the stays will not take their correct proportion of the load. Small reductions in mast stiffness, relative to the Table values, can be accepted provided the modulus deficiency is proportionalty less than that of the inertia.

TABLE D 27.2-STAY EFFICIENCY FACTOR "C"

x h		h v											
n	0,6	0,7	0,8	0,9	1,0	1,2	1,5						
0	0,227	0,269	0,308	0,333	0,353	0,377	0,384						
0,1	0,225	0,267	0,304	0,330	0,350	0,372	0,380						
0,2	0,217	0,258	0,294	0,318	0,338	0,361	0,367						
0,3	0,206	0,243	0,278	0,301	0,320	0,341	0,347						
0,4	0,189	0,225	0,257	0,278	0,296	0,315	0,321						
0,5	0,171	0,202	0,231	0,250	0,265	0,283	0,288						
0,6	0,145	0,172	0,196	0,212	0,225	0,241	0,245						
0,7	0,117	0,139	0,159	0,172	0,183	0,195	0,198						
0,8	0,082	0,097	0,111	0,120	0,128	0,136	0,139						
0,9	0,044	0,052	0,059	0,064	0,068	0,071	0,073						
1,0	0	0	0	0	0	0	0						

TABLE D 27.3—WIRE ROPE DIAMETERS FOR VARYING VALUES OF Aw

Dia.	Circumference		Constr	ruction	
(mm)	(in)	6×7	6×19	7×7	7×19
Macatal	Control of the last	A _w	A _w	A _w	Aw
8	1	0,037	0,037	_	_
9	118	0,045	0,050		
10	11/4	0,057	0,059	0,067	
11	13	0,069	0,069	0,081	
12	11/2	0,088	0,089	0,104	-
14	$1\frac{3}{4}$	0,116	0,114	0,137 ·	0,135
16	2	0,150	0,154	0,176	0,184
18	$2\frac{1}{4}$	0,187	0,185	0,220	0,220
20	$2\frac{1}{2}$	0,240	0,236	0,283	0,282
22	$2\frac{3}{4}$	0,286	0,275	0,338	0,326
24	3	0,338	0,336	0,396	0,386
26	31	0,393	0,402	0,462	0,481
28	$3\frac{1}{2}$	0,466	0,452	0,550	. 0,541
32	4	0,598	0,587	0,703	0,701
36	414	0,769	0,738	0,903	0,881
40	5	0,936	0,943		1,127
44	$5\frac{1}{2}$		1,136		1,352
48	6		1,361		1,604
52	$6\frac{1}{2}$	الما للم يتوليان	1,569		1,872
56	7	-	1,812		2,160

(b) Each force component acting parallel to the mast or post multiplied by the distance (measured perpendicularly to a plane through the neutral axis of that mast or post) of that force from the plane through the neutral axis.

2715 The bending stress at each position on the mast or derrick post is to be calculated from the formula:—

$$f_B = \frac{M_m \ y}{T_m} \ \mathrm{kg/mm^2 \ (ton/in^2)}, \label{eq:fB}$$

where f_B = bending stress at the position under consideration,

M_m = bending moment derived as specified in 2714, in mm kg (in tons),

I_m = moment of inertia of the mast at the height under consideration, in mm⁴ (in⁴),

y = the distance from the neutral axis of the mast to the extreme outer surface at the height under consideration, in mm (in).

2716 The direct compressive stress acting on the mast is to be calculated by summing all the vertical components of span gear, derrick thrust, etc., as applicable, and the weight of the topmast and crosstrees if fitted, and dividing the total by the cross-sectional area of the mast or post at the position under consideration.

The weight of the mast or post tube itself need not be included.

2717 The sum of bending and direct stresses derived from 2715 and 2716 is not at any point to exceed 0,55 Y or 0,35 U + 0,05 Y whichever is the least, if the S.W.L. of no derrick boom exceeds 10 tonnes (tons). Where the S.W.L. of one or more derricks exceeds 10 tonnes (tons) then the stress may increase by 0,010 Y or by 0,007 U, whichever is the least, for each 4 tonne (ton) increase in the S.W.L. of the derrick with the highest S.W.L., where Y = specified minimum yield stress or 0,5 per cent proof stress and U = specified minimum tensile strength plus one half of the specified range of tensile strength. For ordinary shipbuilding mild steel Y may be taken as 25 (16) and U as 46 (29).

The stresses in crosstrees, outriggers, and similar items are to be derived as for masts but using the highest S.W.L. of any derrick actually supported by the crosstree or outrigger.

2718 The effect of torque need not be included in calculating the stresses in masts of normal design, unless the span tackle eyeplate pins to which the derricks are attached to crosstrees or outriggers, are at a distance from

the mast centreline exceeding $\frac{D^2 \text{ mm}}{25,4 \text{ S.W.L.}}$ $\left(\frac{D^2 \text{ in}}{\text{S.W.L.}}\right)$ where D is the mast diameter at half height in mm (in). S.W.L. is the highest safe working load of any derrick supported by the crosstree or outrigger in question, in tonnes (tons).

When torque is taken into account it is to be taken as:-

T = horizontal component of span tension × distance from span eye to centreline of mast or post in tonne mm (ton in).

Shear stress is to be taken as $q = \frac{T}{2 A t}$, where A is the total area enclosed by the outer surface of the mast or post (for circular masts, $A = \frac{\pi (diameter)^2}{4} mm^2 (in^2)$) and t is the wall thickness of the mast or tube, in mm (in).

The total stress in the mast or post is:-

$$\mathrm{f_t} = 0.5 \left(\mathrm{f_m} + \sqrt{(\mathrm{f_m})^2 + 4\mathrm{q}^2}\right) \,\mathrm{kg/mm^2 \, (ton/in^2)}$$

where f_m is the stress value derived from 2717.

2719 The wall thickness, in mm (in), of oval or circular masts and posts is not to be less than:—

FD
$$\sqrt{\text{KY}}$$
 or FD $350 + 2 \times \text{S.W.L.}$ or 100

whichever is the greater,

where D = maximum outside diameter of the mast at corresponding height above the deck, in mm (in),

$$F = \sqrt{ \begin{array}{c} \text{Actual Calculated Stress} \\ \text{Maximum Permitted Stress} \end{array} }$$

K = 1.00 (1.58),

Y = yield stress, in kg/mm² (ton/in²),

S.W.L. = maximum safe working load of any derrick supported by the mast, in tonnes (tons).

The wall thickness, in mm (in), of unstiffened flat sides of masts or posts, with one or more flat sides, is not to be less than:—

$$\frac{\text{FW }\sqrt{\text{KY}}}{200 + 2 \times \text{S.W.L.}} \quad \text{or} \quad \frac{\text{FW}}{60} \tag{2}$$

whichever is the greater,

where K, Y, F, and S.W.L. are as defined above and W is the width, in mm (in), of the flat side at that height or 60 per cent of the width of the mast at that height, measured parallel to the flat side, whichever is the greater.

Where masts are constructed of a combination of curved and flat plates, e.g., curved sides and flat front and back, the value $\frac{\mathsf{FW}}{60}$ may be used in determining the minimum thickness if this is more favourable than $\frac{\mathsf{FD}}{100}$ for the curved plates.

Where flat sides of masts or posts are fitted with vertical stiffeners effectively restrained against tripping, then the values of W used in the formulæ may be taken as the stiffener spacing.

Attention is drawn to the fact that this paragraph is designed to prevent local buckling of the mast plating under compression loading, assuming some local initial unfairness in the plating, and if stiffeners are fitted to permit reductions in plate thicknesses, then they should not be liable to instability under end loading.

Fittings and Details

2720 Masts and derrick posts are to be increased in thickness at the heel and decks and other points of support, and are to be suitably strengthened to take any concentrated loads which may be expected to occur in way of derrick fittings, crosstrees and ventilation openings. They should normally be attached to at least two decks other than the tops of winch houses and small deckhouses of a type giving no effective support, but need not be attached to more than two decks or one deck and the top of a substantial house.

The heels of masts and derrick posts are to be effectively supported.

2721 The design and construction of masts, posts and fittings is to be such as to reduce the likelihood of water collecting in inaccessible parts of the structure.

2722 For lightning conductors, see M 19.

Workmanship

2723 Smithwork should be of a material not liable to work hardening or ageing to a significant degree during normal use.

Rimming steel should not be used.

Where fittings are flame cut from solid material they are to be annealed after cutting and all flame cut faces are to be ground if necessary to give a smooth finish to avoid stress raisers.

Crosstrees

2724 Where outriggers or crosstrees at mast-heads are of unusual spread or where stays are attached to the cross-

trees well clear of the mast, the scantlings of the mast and rigging will be specially considered.

The stresses in crosstrees should not normally exceed 55 per cent of the yield stress of the material or (for items under compression) of the crippling stress of that item.

Section 28

BULWARKS, FREEING PORTS, SCUPPERS AND SANITARY DISCHARGES AND SIDE SCUTTLES

Bulwarks

2801 The height of plate bulwarks on exposed parts of freeboard and superstructure decks, measured above sheathing if fitted, is to be at least 1,0 m (39·5 in) except that where this height would interfere with the normal operation of the ship a lesser height may be approved.

2802 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of 0,07L from the fore perpendicular is not to be more than 1,2 m (4 ft) on Types "A" "B-60" and "B-100" ships and not more than 1,83 m (6 ft) on other types. Elsewhere, bulwark stays are not to be more than 1,83 m (6 ft) apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for cargo gear and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

2803 The arrangements for continuity of strength at the ends of superstructures are to be as required by D 1715. Bulwarks should not be cut for gangway or other openings near the breaks of superstructures and are also to be arranged to ensure their freedom from main structural stresses. (See D 510.)

Freeing Ports

2804 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports and also for draining them.

2805 The minimum freeing port area on each side of the ship, for each well on the freeboard deck (including raised quarter decks), where the sheer in way of the well is standard or greater than standard, is to be as given by the following formulæ. (See also 2807.)

(a) Where the length (I) of the bulwark in the well is 20 m (66 ft) or less:—

Area required = $0.7+0.035 I \text{ m}^2$ (Area required = $7 \cdot 6+0 \cdot 115 I \text{ ft}^2$

(b) Where the length (I) exceeds 20 m (66 ft):—

Area required = $0.07 I \text{ m}^2$ (Area required = $0.23 I \text{ ft}^2$) I need not be taken greater than 0.7 L.

If the average height of the bulwark exceeds 1,2 m $(3 \cdot 9 \text{ ft})$ or is less than 0,9 m (3 ft) the freeing port area is to be increased or decreased respectively by 0,004 m² per metre of length of well for each 0,1 m difference $(0 \cdot 04 \text{ ft}^2 \text{ per foot of length of well for each foot difference})$ in height from Rule.

The minimum freeing port area for each well on superstructure decks is to be half the area given by the above.

Type "B" ships with reduced freeboards will require to have freeing port area greater than given above.

2806 In ships with no sheer the freeing port area is to be increased by 50 per cent. Where the sheer is less than the standard, the percentage is to be obtained by interpolation.

2807 Where ships are fitted on the freeboard deck with continuous trunk or continuous hatchside coaming in association with bulwarks, the minimum area of freeing port openings is to be not less than 20 per cent of the total area of bulwarks when the width of trunk or hatch is 0,4B or less and not less than 10 per cent of the total area of bulwarks when the width of the hatch is 0,75B or more, with intermediate values by interpolation.

2808 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

2809 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

2810 The lower edges of freeing ports are to be as near to the deck as practicable and the openings are to be protected by rails spaced approximately 230 mm (9 in) apart. If hinged shutters are fitted to freeing ports ample clearance is to be provided to prevent jamming, and if securing appliances are fitted these appliances are to be of approved construction. Hinges are to have pins or bearings of non-corrodible material.

Scuppers and Sanitary Discharges

2811 Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

2812 In ships over 150 m (492 ft) in length, scupper openings are not to be cut in the sheerstrake above deck level within 0,5L amidships, and in no case in way of discontinuities such as breaks of superstructures. See D 510.

When scuppers or discharges are cut in the shell or superstructure sides compensation may require to be fitted.

2813 Scuppers and discharges which drain spaces below the freeboard deck or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers or to suitable sanitary tanks in the case of sanitary pipes. Alternatively, they may be led overboard provided the spaces drained are above the load waterline, and the pipes are fitted with efficient and accessible means of preventing water from passing inboard. See 2814.

2814 In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the freeboard deck. An indicator is to be fitted at the control position showing whether the valve is open or closed.

Where, however, the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,01L the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided the inboard valve is always accessible for examination under service conditions.

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,02L, consideration will be given to proposals for fitting a single automatic non-return valve without positive means of closing.

2815 Scuppers and discharge pipes originating at any level, which penetrate the shell either more than 450 mm (17.5 in) below the freeboard deck or less than 600 mm (23.5 in) above the summer load waterline are to be fitted with an automatic non-return valve at the shell.

This valve, unless required by 2813, may be omitted provided the pipe thickness is not less than:—

$$\frac{\text{Diameter of pipe in mm}}{24} + 6.5 \text{ mm}$$

$$\left(\frac{\text{Diameter of pipe in inches}}{24} + 0.25 \text{ in}\right)$$

but need not exceed 12,5 mm (0.50 in).

2816 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

2817 Plans showing the arrangement of scuppers for draining refrigerated cargo compartments are to be submitted for consideration.

Materials for Valves, Fittings and Pipes

2818 All valves required by 2814, and shell fittings where no valves are required, are to be of steel, bronze or other approved ductile material; ordinary cast iron is not acceptable. Material submitted for approval is to have an elongation not less than 12 per cent on a gauge length of $5,65\sqrt{S_0}$, where S_0 is the actual cross-sectional area of the test piece.

All these items, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

The lengths of pipe attached to the required valves or elbow pieces are to be of galvanized steel of standard steam pipe quality or other equivalent approved material. See also F 706.

Protection of Pipes and Valves

2819 In all cargo spaces and other areas where damage might be likely, all scuppers and discharges including their valves, controls and indicators are to be well protected. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, fork lift trucks or similar items is a possibility.

Side Scuttles

2820 Side scuttles, together with their glasses if fitted, and deadlights, are to be of approved design and of approved material other than ordinary cast iron. They are to be metal framed and glasses are to be retained by a metal glazing bead.

2821 Side scuttles to spaces below the freeboard deck or to spaces within enclosed superstructures are to be fitted with efficient inside deadlights permanently attached and capable of being closed and secured watertight.

2822 No side scuttle is to be fitted in a position so that its sill is below a line drawn parallel to the freeboard deck at side and having its lowest point 2,5 per cent of the breadth B above the load waterline or 500 mm (19.5 in) whichever is the greater distance.

2823 In passenger ships, the position and construction of the side scuttles will be specially considered. (See also F 813.)

Section 29

VENTILATION, AIR PIPES AND SOUNDING PIPES

Ventilator Coamings

2901 The minimum height of ventilator coamings above the upper surface of decks exposed to the weather, measured above sheathing if fitted, is to be as follows:—

Ventilators situated in position 1 (see D 2605) 900 mm (35.5 in),

Ventilators situated in position 2 (see D 2605) 760 mm (30 in).

Where it is intended to fit patent ventilators the minimum height of coaming will be specially considered.

2902 Ventilator coamings having a height greater than 900 mm (35·5 in) are to be specially supported.

2903 The thickness of steel ventilator coamings is to be not less than:—

$$5.5 + \frac{\delta}{100}$$
 mm $\left(0.22 + \frac{\delta}{100} \text{ in}\right)$

where δ is the internal diameter of the coaming. The thickness need not exceed 10 mm (0·40 in), but is not to be less than 7,5 mm (0·30 in).

2904 The deck plating in way of ventilator coamings is to be efficiently stiffened.

2905 All ventilator coamings are to be provided with strong plugs and canvas covers or equally efficient weather-tight closing appliances unless (a) the height of the coaming is greater than 4,5 m (14·8 ft) where 2901 requires a minimum height of 900 mm (35·5 in), or (b) the height of the coaming is greater than 2,3 m (7·5 ft) where 2901 requires a minimum height of 760 mm (30 in).

These closing appliances are to be either permanently attached to the ventilator coaming or else stowed in a convenient and accessible position close to the coaming for which they are intended to be used.

2906 In particularly exposed positions the heights, scantlings and/or supports of ventilator coamings may be required to be suitably increased above the values given above.

Positioning of Ventilators

2907 Special care is to be taken when designing and positioning ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress.

Where practicable, ventilators should be sited clear of highly stressed parts of the structure. In general, ventilation openings should not be cut in deck girders within 1,5 m (5 ft) of pillars or of the girder endings.

Minor Ventilators

2908 Mushroom, gooseneck and other similar minor ventilators are to be strongly constructed and efficiently secured to the deck plating.

Fire Precautions

2909 For passenger ships, see F 815 to F 817.
For cargo ships, see F 1004.

Air and Sounding Pipes

2910 Air and sounding pipes are to comply with the requirements of Chapter E.

2911 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is not normally to be less than:—

On the freeboard deck 760 mm (30 in), On superstructure decks 450 mm (17.5 in).

These heights are to be measured above sheathing, where fitted.

Lower heights may be approved in cases where these are essential for the working of the ship, provided the design and arrangements are otherwise satisfactory.

2912 All openings of air and sounding pipes are to be provided with permanently attached satisfactory means of closing to prevent the free entry of water.

2913 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

2914 Air and sounding pipes are to be well protected in all spaces. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, fork lift trucks or similar items is a possibility.

Section 30

CEILING AND CARGO BATTENS

Ceiling

3001 In ships having double bottoms, ceiling is to be laid over the bilges and under hatchways; the ceiling over the bilges is to be arranged with portable sections that are readily removable. Ceiling under hatchways may be omitted provided the thickness of the inner bottom plating is increased by 2 mm (0.08 in).

3002 The spaces between the frames at the top of the bilge ceiling are to be closed by wood chocks and cement or other suitable means.

3003 Ceiling is to be laid either directly on the inner bottom plating embedded in a suitable bituminous or epoxy composition, or on battens providing a clear space of at least 12.5 mm (0.5 in) for drainage.

3004 The thickness of wood ceiling is not to be less than 65 mm (2.5 in).

Where it is intended to use plywood or other forms of ceiling of an approved type instead of planking, the thickness will be considered for each case.

3005 Where the covers or fittings of the manholes of the inner bottom in cargo holds project above the plating, they are to be protected by a steel coaming around each manhole, fitted with a hatch of wood or steel.

Cargo Battens

3006 Cargo battens are to be fitted in the holds from above the upper part of the bilge to the under side of beam knees, and in all cargo spaces in 'tween decks and super-structures up to the under side of beam knees.

3007 Wood cargo battens are to be 50 mm (2 in) in thickness; the clear space between adjacent rows is, in general, not to exceed 230 mm (9 in).

If it is intended to use other materials instead of battens, the thickness will be considered in each case.

3008 Battens may be dispensed with at the request of the Owners; the notation "NS" will appear in the Register Book.

Cross-references

3009 For ceiling in ships which are regularly discharged by grabs, see D 907.

For arrangements in way of refrigerated holds, see N 415 and N 416.

Section 31

PROTECTION OF STEELWORK

Cementing

3101 In double bottom tanks under the boiler room, the frames and shell plating are to be effectively covered by an approved type of cement or other coating unless the tanks are used solely for oil fuel; elsewhere in the double bottom the cement or coating may be dispensed with, but the requirements of 3102 would then apply. The bilges are to be cemented or effectively coated.

Chapter D

Painting

3102 All steelwork not protected as required by 3101 is to receive at least two coats of paint of suitable composition except inside tanks intended for oil; tanks not intended for oil may be coated with cement wash as an alternative to painting. (See F 822 and F 1005).

An approved system of corrosion control may be adopted in tanks as an alternative to painting. See D 110.

General

3103 Millscale should be removed from external shell plating, and it is recommended that shot blasting, pickling or other equally effective means be employed for this purpose. If flame cleaning is adopted, it is to be followed by wire brushing or grinding. Where reliance is placed on weathering and wire brushing, the coating of the external surface should be delayed as long as possible to facilitate the removal of the millscale.

3104 When the millscale is removed by methods less effective than shot blasting, it is desirable, when several months elapse between the launching and commissioning, to drydock the ship immediately before she goes into service. In these circumstances, it is also desirable to drydock a ship when she has been in service about six months.

Section 32

WELDING

General

3201 Where electric arc welding is to be used for the main structure the arrangement of plating, disposition and type of joints, together with the proposed sequence of prefabrication, assembly and welding are to be submitted for approval. The extent to which automatic welding (whether deep penetration or otherwise) is to be used should be indicated.

Details of welded connections of main structural members with type and size of welds are to be clearly indicated on the plans submitted for approval.

The approved arrangements, sequences and procedures are not to be departed from without approval.

3202 The structural arrangements are to be such as will allow easy access for welding operations and facilitate the use of downhand welding wherever possible.

The type and disposition of connections and sequences of welding are to be so planned that any restraint during welding operations is reduced to a minimum. 3203 The electrodes used are to be approved by the Committee and are to be suitable for the type of joint and grade of steel as follows:—

Grade 1-for Grade A steel,

Grade 2-for Grades A, B or D steel,

Grade 3-for Grades A, B, D or E steel.

When joining two different grades of steel of the same tensile properties, electrodes suitable for the lower grade are generally acceptable, except at discontinuities or other points of stress concentration. The requirements for electrodes are given in P 11.

Primers and Coatings

3204 Where primers are applied over areas which will subsequently be welded they are to be of a quality approved by the Society as having no deleterious effect on the finished weld.

Inspection

3205 Effective arrangements are to be provided for the inspection of finished welds in order to ensure that all welding has been satisfactorily completed.

Visual inspection may require to be supplemented by other forms of non-destructive crack or flaw detection methods for the examination of important structural welds. The extent of such examination is to be to the Surveyor's satisfaction but particular attention should be paid to the following locations:—

- (a) Junction and crossings of seams and butts in strength deck, sheerstrake, side and bottom shell within 0,4L amidships,
- (b) Butts of keel plating and rounded sheerstrake within 0,4L amidships,
- (c) Insert plates in way of hatch openings in the strength deck.

A system of radiographic examination should be used wherever practicable and where this is available the Surveyors are to collaborate with the Builders in this system of inspection. (See also 3219 (f) for higher tensile steel.)

All defective sections of welds are to be cut out, carefully re-welded and re-examined.

3206 Alternative proposals for methods of welding considered by the Committee to be equivalent to those set forth in the Rules will be accepted.

Joints and Connections

3207 BUTT WELDS. In general, the edges of plates to be joined by manual welding are to be bevelled on one side or on both sides of the plates to provide an included angle of from 50 to 60 degrees.

Where it is desired to adopt other forms of edge preparation full details are to be submitted for approval.

A back sealing run is to be applied, after suitable back gouging, to all butt welds where main welding is carried out from one side only, unless the welding process has been specially approved for use without a back run.

3208 FILLET WELDS. The dimensions of fillet welds for structural connections are to be as required by Table D 32.1 and associated Notes.

3209 TEE CONNECTIONS. The throat thickness (leg length) of the fillets is generally to be governed by the thickness of the thinner of the two parts being joined.

Where the difference between the thicknesses of the parts to be joined is considerable, the size of the fillet will be specially considered (see Table D 32.1 Note 1 for slab type longitudinals).

Tee connections should be made by fillets on both sides of the abutting plate. Where the abutting plate is bevelled a sealing run should be applied on the reverse side.

3210 INTERMITTENT FILLETS. The length of intermittent welds is to be measured over the correctly proportioned fillet, clear of end craters.

Intermittent welds are to be doubled at the ends of all structural members, and the welding is to be carried round the ends of brackets, lugs, etc.

3211 SCALLOPS AND NOTCHES. The details of scalloped construction are given in Fig. D 32.1. All scallops are to have well rounded corners and smooth edges. Scallops are not to be cut in way of the toes of bracket connections or at other parts where stress concentrations may develop.

Scallops in side frames, longitudinals and stiffeners are to be omitted for at least 230 mm (9 in) on each side of the intersection with a primary supporting member.

Notches in primary supporting members are not to be larger than necessary, and are to have well rounded corners and smooth edges. When notches occur at points where stress concentration may develop, such as adjacent to the toes of brackets, a welded collar or equivalent reinforcement is to be fitted.

Additional Attachment

3212 Welded connections may require to be increased to meet particular local stresses, or where otherwise necessary.

Workmanship

3213 Welding operators are to be proficient in the type of work on which they are engaged. A sufficient number of skilled supervisors is to be provided to ensure

effective control at all stages of assembly and welding operations. The welding plant and appliances are to be suitable for the purpose intended and are to be maintained in an efficient condition.

3214 Procedures for the welding of all joints are to be established for the types of electrode, edge preparation and welding position proposed. For this purpose, the Surveyors may require sample tests to be prepared under similar conditions to those which will obtain during construction.

The diameter of electrode, current, voltage, rate of deposit and number of runs are to conform, so far as practicable, to those established in accordance with 3213. Provision is to be made for checking the current in the vicinity of the arc.

3215 The preparation of plate edges is to be accurate and uniform. All joints are to be properly aligned and closed or adjusted before welding. Excessive force is not to be used in fairing and closing the work. Means are to be provided for holding the work in proper alignment without rigid restraint during welding operations.

Where excessive gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be to the satisfaction of the Surveyors.

3216 Tack welding should be kept to a minimum and where used should be equal in quality to the finished welds. All defective tack welds should be cut out before completing the finished welds.

Care should be taken when removing tack welds and temporary fittings used for assembly to ensure that the material of the hull is not damaged.

3217 The surfaces of all parts to be welded are to be clean, dry and free from rust, scale and grease. The surfaces and boundaries of each run of deposit are to be thoroughly cleaned and freed from slag before the next run is applied.

Before a manual sealing run is applied to the back of a weld the original root run is to cut back to sound metal.

Welding is to proceed systematically, each welded joint being completed in proper sequence without undue interruption.

Adequate protection is to be provided where welding is required to be carried out in exposed positions in wet, windy or cold weather. In cold weather, precautions should be taken to screen and pre-warm the work where necessary to prevent too rapid cooling of the weld; special care is necessary when welding thick material.

3218 All finished welds are to be sound, uniform and substantially free from slag inclusions, porosity, undercutting or other defects. Care is to be taken to ensure thorough penetration and fusion.

TABLE D 32.1

DETAILS OF VARIOUS FILLET WELD CONNECTIONS

ITEM	*WELD FACTOR	REMARKS
THE ANALYSIS AND ANALYSIS ANALYSIS AND ANALYSIS ANALYSIS AND ANALYSIS		
TRANSVERSE FRAMING	See D 733	continuous in way of beam knees and tank
ment of the sum of the learning against	Bee D 155	side brackets
	0.10 (0.14)	elsewhere: frame spacing less than 850 mm
Hold frames (including ice frames) to shell	0,10 (0 11)	(33.5 in)
	0,12 (0.17)	elsewhere: frame spacing 850 mm (33.5 in
THE PERSON NAMED IN COLUMN TO PERSON OF THE PERSON OF	2302 AT 504	or more
Side frames in deep tanks, oil fuel tanks and in		the first property of the property of the party of the pa
panting region	0.12 (0.17)	excluding 'tween decks
'Tween deck frames to shell	0,10 (0.14)	and full the safe assembly and another safe and the
	0,12 (0.17)	in fore peaks
D tt C t1 11 1 (1 1 (1	0,21 (0.30)	in way of strengthened bottom forward (se
Bottom frames to shell and floors, and floor plates to shell		D 1007)
plates to shell	0,21 (0.30)	in aft peaks (see Note 5)
The state of the s	0,10 (0.14)	elsewhere
Floors and cross ties to frames in fore peak	0,10 (0.14)	at any polyson and well If a pay entire in the
Floors and cross ties to frames in aft peak	0,21 (0.30)	see Note 5
Frames to tank side brackets	See D 733	
DOUBLE BOTTOMS (TRANSVERSELY FRAMED)		
	0,35 (0.50)	if watertight
Centre girder to keel	0,26 (0.37)	elsewhere
	0,35 (0.50)	if watertight
The state of the s	0,26 (0.37)	in engine space and under thrust blocks (n
Centre girder to inner bottom {	SALES VE SEV	scallops)
the latter of th	0,21 (0.30)	elsewhere (no scallops)
N	0,26 (0.37)	under engine, thrust and boiler bearers
Non-watertight floors to centre girder {	0,14 (0.20)	elsewhere
Non-watertight floors to margin plate	To depend	generally 0,44 (0.63) in panting region and
	on design	0,35 (0·50) elsewhere
despired the first of the sale to fe	0,21 (0.30)	in way of strengthened bottom forward (se
Non-watertight floors elsewhere and non-	A SAN SAN SAN SAN SAN SAN SAN SAN SAN SA	D 1007)
watertight side girders	0,21 (0.30)	to inner bottom under engine and thrus
waterught bate gretors		bearers
	0,10 (0.14)	elsewhere
Longitudinal foundation girders under main		T 1 6 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
diesel engines	0.01 (0.00)	In general, full penetration welding is require
Reversed frames to bracket floors and inner	0,21 (0.30)	under engine and thrust bearers
Tank side brackets to tank top and margin	0,10 (0.14)	elsewhere
plate	0,44 (0·63) 0,35 (0·50)	in panting region elsewhere—generally
Tank top or margin plate to shell	0,35 (0·50) 0,35 (0·50)	elsewhere—generally
Boundaries of watertight and oiltight floors,	0,55 (0.50)	
side girders or double bottom wells	0,35 (0.50)	
Stiffeners of watertight and oiltight floors, side	0,55 (0.50)	
girders or double bottom wells	0.14 (0.20)	James Assessed Lames
For bottom frames to shell and floor plates to	. U.II. (U. 20)	The state of the s
shell		see Transverse Framing above
	or and the second	
LONGITUDINAL FRAMING AND		
DOUBLE BOTTOMS LONGITUDINALLY		
FRAMED		a diagram
001 Y 7 2 2 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1	0,12 (0.17)	in panting region, in tanks and where spacing
Side longitudinals in holds, tanks and 'tween		exceeds 850 mm (33.5 in) (see Note 1 and
decks	2.22 12.20	Note 5)
	0,10 (0.14)	elsewhere (see Note 1)

^{*} Weld sizes in metric units are based upon throat thickness and in British units on leg length.

TABLE D 32.1—continued

ITEM	*WELD FACTOR	REMARKS
LONGITUDINAL FRAMING AND DOUBLE BOTTOMS LONGITUDINALLY FRAMED—continued	0,17 (0.24)	generally to shell. Up to 0,35 (0.50) when highly loaded. Continuous in way of end
Web frames supporting side longitudinals	0,12 (0.17)	brackets to face bars or face plates of area greater than 39 cm ² (6 in ²)
Bottom longitudinals to shell and floors	$ \begin{cases} 0,10 & (0.14) \\ 0,12 & (0.17) \\ 0,10 & (0.14) \end{cases} $	elswhere for 0,25L forward (see Note 1 and Note 5) elsewhere (see Note 1 and Note 5)
Bottom longitudinals of the flat bar or plate type to shell	0,25 (0·35) Continuous weld	but need not exceed 5,5 mm (0·30 in) hand, or 4,5 mm (0·25 in) automatic. See also Note 1
Tank top longitudinals to inner bottom	$ \begin{cases} 0.12 & (0.17) \\ 0.10 & (0.14) \end{cases} $	under ore holds (see Note 1 and Note 5) elsewhere (see Note 1 and Note 5)
Hopper tank and wing tank longitudinals	0,12 (0.17)	see Note 1 and Note 5
Non-watertight floor boundaries Watertight and oiltight floor boundaries	$ \left\{ \begin{array}{ccc} 0.12 & (0.17) \\ 0.26 & (0.37) \\ 0.35 & (0.50) \end{array} \right. $	for 2 spaces at ends (see D 1007 for fore end)
Tank top, margin plate and girders to shell to b	e as for double bottom	is (transversely framed) above
DECKS, BEAMS AND DECK LONGITUDINALS Strength deck to shell	depends on design depends on design 0,44 (0.63) 0,21 (0.30) 0,14 (0.20) 0,14 (0.20) 0,12 (0.17) 0,21 (0.30) 0,10 (0.14) 0,10 (0.14) 0,25 (0.35) Continuous weld See D 733	full penetration weld generally 0,21 continuous (0·30 continuous) generally 0,21 or 0,14 (0·30 or 0·20) continuous continuous see Note 5 see Note 5 see Note 1 and Note 5 but need not exceed 5,5 mm (0·30 in) hand, or 4,5 mm (0·25 in) automatic. See also Note 1 continuous 6,5 cm² (1 in²) of welding for beams not exceeding 200 mm (8 in) and 9,5 cm² (1·5 in²) of welding for beams exceeding 200 mm (8 in) depth
DECK GIRDERS, TRANSVERSES AND WEBS Connections to plating End brackets Web to face bars	$ \begin{cases} 0.21 & (0.30) \\ 0.14 & (0.20) \\ 0.35 & (0.50) \\ 0.12 & (0.17) \\ 0.10 & (0.14) \end{cases} $	continuous in way of end brackets elsewhere generally continuous face bar area greater than 39 cm ² (6 in ²) face bar area not exceeding 39 cm ² (6 in ²)
DEEP TANKS, PEAK TANKS AND BUNKERS Bulkhead boundary connections Stiffeners Stiffener brackets	$ \begin{cases} 0,39 & (0.55) \\ 0,35 & (0.50) \\ 0,44 & (0.63) \\ 0,12 & (0.17) \end{cases} $	at bottom and bilge (see Note 5) at deck and side (see Note 5) at ends of swedges (see D 1817) see D 1817 and D 1910 see Note 6, D 1817 and D 1910
Horizontal girders to shell and bulkheads Horizontal girders to girder brackets	0.26 (0.37) $0.14 (0.20)$ $0.26 (0.37)$	in way of end brackets clear of end brackets generally continuous
Girder webs to face bars	$\int 0.12 (0.17)$	face bar area greater than 39 cm ² (6 in ²)
	0,10 (0.14)	face bar area not exceeding 39 cm ² (6 in ²)

^{*} Weld sizes in metric units are based upon throat thickness and in British units on leg length.

TABLE D 32.1—continued

ITEM	*WELD FACTOR	REMARKS
WATERTIGHT BULKHEADS, FLATS		CINA DERIVATA MAPAGETTINO
AND TUNNELS		
Bulkhead boundary connections	0,35 (0.50)	if thickness less than 6 mm (0.24 in) (se
Buiknead boundary connections	0,55 (0.50)	Note 2 to Table D 32.1)
Stiffeners	0,10 (0.14)	generally (see Note 5)
	0,10 (0.14)	when supporting pillars above
T1 1 C 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	0,14 (0.20)	as required by D 1817
	0,44 (0.03)	see Note 6 and D 1817
Brackets and lugs		see Note 6 and D 1817
	The state of the s	The second out of the factor of the second
DECKHOUSES	0.95 (0.50)	
Connections to deck	0,35 (0.50)	
Stiffeners	0,10 (0.14)	N. C. W. M. D. LEV. J. D. LEV.
Stiffener end connections	OTH OF ITO	see Note 6, Tables D 17.4 and D 17.5
NON-WATERTIGHT BULKHEADS	0.14 (0.00)	West of the second seco
Boundary connections to tank top	0,14 (0.20)	no scallops
Boundary connections elsewhere	0,10 (0.14)	
Stiffeners used as pillars	0,14 (0.20)	when supporting pillars above
Stiffeners elsewhere	0,10 (0.14)	
PILLARS	0.10 (0.14)	- 1- 0.95 (0.50) :
Pillars built of rolled sections or plates	0,10 (0.14)	up to 0,35 (0·50) in special cases—see als D 1410
End connections of widely spaced pillars	0,35 (0.50)	see also D 1410
Bulkhead stiffeners acting as pillars supporting	641 16 341	
pillars above	0,14 (0.20)	see also D 1817
HATCHWAYS	1000-01-100	
	0,35 (0.50)	generally
	0,44 (0.63)	generany
(N) 1 (1.00)	0,10 (0.14)	may be increased in special cases
Coaming stiffeners Hatch beam bars and face plates to webs, and	0,10 (0.14)	may be increased in special cases
stiffeners of pontoon covers	0.10 (0.14)	generally-may be increased in special cases
stilleners of politoon covers	0,10 (0.14)	generally—may be increased in special cases
VENTILATORS	0.95 (0.50)	
Coaming connection to weather decks	0,35 (0.50)	
Elsewhere	0,21 (0.30)	
2000 200 200 200 200 200 200 200 200 20		- a series - selfate at excita-
STEMS AND STERNFRAMES	0.91 (0.90)	
Stem breasthooks and stiffeners	0,21 (0.30)	
Sternframes (main load-bearing items)	0,44 (0.63)	
Sternframes elswhere	0,21 (0.30)	
RUDDERS		- HILLSHIT HILL
Fabricated mainpiece and mainpiece to rudder		
side plates and webs	0,44 (0.63)	
Elsewhere	0,21 (0.30)	
Slot welding	0,44 (0.63)	The second second second
M. A. CITTO	1 100	
MASTS Main structure	0,44 (0.63)	
Cargo gear fittings	full penetration	
confee four monifo	generally required	
Minor fittings	0,21 (0·30)	
minor noungs in in in in	0,21 (0.00)	

^{*} Weld sizes in metric units are based upon throat thickness and in British units on leg length.

NOTES.—TABLE D 32.1

1. Thickness to be used in determining throat thickness (leg length) is generally to be that of the thinner of the two parts being joined.

Where slab type longitudinals are fitted to the bottom shell or upper deck within 0,4L amidships the thickness used to determine the throat thickness (leg length) is to be taken as not less than half the thickness of the longitudinal.

Where the difference between the thicknesses of the parts to be joined is considerable the size of fillet will be specially considered.

2. Throat thickness (leg length) for double continuous fillets is to be the product of the plate thickness and the weld factor given in Table D 32.1, except that where automatic deep penetration welds are used the values so derived may be reduced by 15 per cent. In no case (except for slab type longitudinals) is the throat thickness (leg length) to be less than $0.21 \times \text{plate}$ thickness ($0.30 \times \text{plate}$ thickness) nor is it to be less than 3.5 mm (0.18 in) for hand and automatic welding or 3 mm (0.16 in) for automatic deep penetration welding.

For hand welded fillet welds on internal bulkheads not exceeding 6 mm (0.24 in) in thickness a minimum throat thickness (leg length) of 3 mm (0.16 in) is acceptable.

3. Throat thickness (leg length) for intermittent fillets is to be as given by the formula:—

Throat thickness (leg length) = plate thickness×weld factor $\times \frac{d}{s}$ where d and s are defined in Fig. D 32.1

The length s should not be less than 75 mm (3 in) and the ratio of s and d is to be such that the required throat thickness (leg length) does not exceed 0,49×plate thickness (0·70×plate thickness) or 4,5 mm (0·24 in) whichever be the greater.

In no case, however, is the throat thickness (leg length) of intermittent fillet welds to be less than $0.28 \times \text{plate}$ thickness ($0.40 \times \text{plate}$ thickness) or 3.5 mm (0.18 in) whichever be the greater.

4. Leg length of welds is to be not less than 140 per cent of the throat thickness derived as above.

or in British units:-

Throat thickness of welds is to be not less than 70 per cent of the leg length derived as above.

- 5. Fillet welds in after peak tanks and on after peak bulkhead stiffeners and all welding in deep tanks intended for chemicals and edible liquids are to be continuous. Where the thickness of bottom or deck longitudinals exceeds the thickness of the shell or deck plating the welding is to be continuous. See also D 1007.
- 6. Welding at the ends of bulkhead stiffeners, etc. (whether associated with brackets or lugs) is to give, generally, a weld area (length of weld×throat thickness) of 25 per cent of the cross-sectional area of the stiffener with a minimum of 6.5 cm^2 (1 in²). (See also D 1817, D 1910 and Tables D 17.4 and D 17.5).
- 7. The welding of girders, webs, beams and frames to shell and deck in way of end brackets or knees that require continuous welds, should also be continuous.

STAGGERED INTERMITTENT

To be doubled at ends. See D 3210

CHAIN INTERMITTENT

SCALLOPED FRAMES, LONGITUDINALS, STIFFENERS, etc., WITH DOUBLE FILLET WELDS

Welding to be carried round the ends of all lugs

See also D 3210 and D 3211

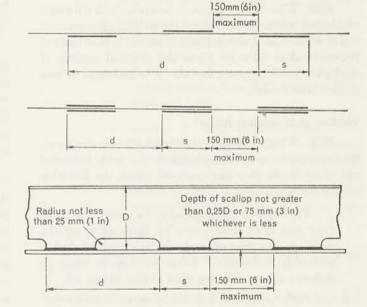


Fig. D 32.1 Weld Types

Welding of Higher Tensile Steel

3219 Where higher tensile steel is employed the requirements as laid down in this Section are to be carried out in so far as they are applicable, with the following amendments:—

- (a) Electrodes are to be of a type approved by the Society for use with higher tensile steel,
- (b) Welding procedures and techniques are to be demonstrated as satisfactory by shipyard tests (See 3214),
- (c) Preheating and/or other heat treatment during or after welding may be required where conditions of high restraint are unavoidable, or when the ambient temperature is unusually low, or more generally, when desirable due to the design of the weld, size of electrode, and the thickness and chemical analysis of the steel being welded,
- (d) Fillet welds are to be continuous,
- (e) Butt welds are to have a smooth profile without excessive build-up,
- (f) Random non-destructive testing is to be carried out especially at highly stressed items. Magnetic crack detecting or equivalent tests are to be used at the ends of fillet welds, tee joints and other joints where welds join or cross in main structural members. Butt welds and highly stressed items elsewhere are to be X-rayed or given other equivalent tests.

3220 Where the structure incorporates both mild steel and higher tensile steel details of the welding arrangements and procedures at the interchange joints are to be submitted for approval in all cases where the chemical analysis of the higher tensile steel requires that it be preheated or heat treated after welding.

Welding of Aluminium Alloys

3221 Where welding of aluminium alloys is employed, the requirements as laid down in this Section are to be carried out in so far as they are applicable, with the following additions:—

The edges of the material to be welded are to be clean and freed from grease by chemical or solvent cleaning. The joint edges should be scratch brushed—preferably immediately before welding—in order to remove oxide or adhering films of dirt, filings, etc.

Parts to be welded should be set up in such a way that contraction stresses are kept to a minimum. For welding processes and filler wire, see P 14.

Section 33

STRUCTURAL DETAILS

3301 Special attention is to be paid to structural continuity. Abrupt changes of shape or section and all sharp corners are to be avoided. The endings of bulwarks, bilge keels or similar attachments to the hull are to be gradually tapered.

3302 For details of openings in strength deck, see D 407 to D 409.

3303 Bulwarks, fairlead stools, mouldings and other fittings are not to be welded to the top edge of the sheer-strake within 0,5L amidships. The top edge of the sheer-strake is to be free of all notches and is to be smooth.

3304 Manholes, lightening holes, slots, scallops and notches should be avoided in way of concentrated loads, including high shear loads. In particular, manholes and similar openings should not be cut in vertical or horizontal plate webs in narrow cofferdams within one-third of the length of the webs from each end, nor in floors or double bottom girders close to the toes of bilge or bulkhead brackets unless the stresses in the remaining web plating are calculated and found to be satisfactory. (See D 933, D 945 and D 947.)

3305 Where practicable, pillars and bulkheads should be placed in the same vertical line. Beam slots in girders, etc., adjacent to concentrated loads should be collared.

3306 The toes of brackets, etc., should not land on unstiffened panels of plating unless the bracket is well hollowed out and extends close to an adjacent stiffener.

Where large brackets are fitted, sharp angles at their toes should be avoided by making the free edge of the bracket concave or by other means. Special care should be taken to avoid notch effects at the toes of brackets, etc.

3307 The standard of welding and general workmanship of bilge keels, rubbing bars and other similar items attached to highly stressed parts of the ship should be as high as that for the main structural items themselves. The welding of minor items to main structural members is to be avoided where possible.

The ends of bilge keels are to be well sniped and arranged to land in way of an internal stiffener such as a frame, floor or transverse. Such items should be continuous over shell butts, the butt being first made flush in way.

Ratholes and scallops should be avoided. The butts of bilge keels should be completed before the bilge keels are welded to the shell. (See D 517).

3308 The use of backing bars in highly stressed welds is to be avoided where possible. When backing bars are unavoidable, (e.g., in certain rudder designs) special care is to be taken to ensure accurate fit-up. Welding, especially in way of butts of the backing bar, is to be of the highest quality. (See also D 2220 for welding of rudders.)

3309 When stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these welds are to be made flush in way of the faying surface. Similarly, for butt welds in webs of stiffening members the butt weld should be completed and generally made flush with the stiffening member before the fillet weld is made.

Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of such a size, and in such a position, that a satisfactory weld can be made.

3310 Where thick plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The taper is generally not to exceed 1 in 3.

Where butt welds form a Tee junction, the "leg" of the Tee should, where practicable, be completed (including the back run, if any) before the "table" is welded.

If all three plates are in position when the "leg" of the Tee is welded, steps should be taken to protect the cross plate either by wedging up the two plates adjoining the "leg" of the Tee clear of the cross plate, or else by using a shield of some sort. The "leg" welding should be completed full at the junction and then chipped flush to remove crater cracks, etc.

Where the "leg" is welded before the cross plate is fitted, it is good practice to fit a temporary "run off" plate to allow the Tee "leg" welding to continue past the parent plate edge. When this is done, the run off plate should be clamped in position and not welded unless a trimming edge has been left on the parent plates, in which case the run off plate may be welded to one only of the parent plates.

Where butt welds have been chipped or ground flush to permit fillet welds of abutting members to cross them, care is to be taken to ensure that the ends of the flush portion run out smoothly without notches or sudden change of section.

3311 In higher tensile steel stiffening members particular attention is to be paid to air holes and drain holes. These should be cut clear of the fillet weld wherever this is practicable. Where it is necessary to arrange such holes flush with the attached plating, the holes are to be of elliptical shape.

Section 34

EQUIPMENT

General

3401 The regulations governing the assignment of the figure 1 for equipment are contained in B 201 and B 202.

3402 To entitle a ship to the figure 1, the equipment is to be in accordance with the following requirements and Table D 34.1. For ships engaged on a special or restricted service, an equipment differing from the Table requirements may be approved by the Committee if considered suitable for the particular service on which the ship is to be engaged.

Equipment Number

3403 The equipment of anchors, chain cables, wires and ropes given in Table D 34.1 and associated Notes is based on an "Equipment Number" which is to be calculated as follows:—

Equipment Number $=\Delta^{\frac{2}{3}} + 2 Bh + \frac{A}{10}$

or in British units:-

Equipment Number =

$$1.012 \, \Delta^{\frac{2}{3}} + \frac{\mathsf{Bh}}{5.382} + \frac{\mathsf{A}}{107.64}$$

where Δ = moulded displacement, in tonnes (tons), to the summer load waterline,

B = greatest moulded breadth, in metres (feet),

h = freeboard amidships, in metres (feet), from the summer load waterline plus the sum of the heights at the centreline, in metres (feet), of each tier of houses having a breadth greater than B/4. (See also 3404, 3405 and 3406).

A = area, in m² (ft²), in profile view of the hull, within the Rule length of the vessel, and of superstructures and houses above the summer load waterline, which are within the Rule length of the vessel, and also having a width greater than B/4. (See also 3405 and 3406).

3404 When calculating h, sheer and trim are to be ignored.

3405 If a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less, then the wide house is to be included, but the narrow house ignored.

3406 Screens and bulwarks more than 1,5 m (4.9 ft) in height are to be regarded as parts of houses when determining h and A.

Anchor Weights

- 3407 The weight per anchor, of bower anchors, given in Table D 34.1 is for anchors of equal weight. The weight of individual anchors may vary by \pm 7 per cent of the Table weight provided that the total weight of anchors is not less than would have been required for anchors of equal weight.
- 3408 The weight of the head, including pins and fittings, of an ordinary stockless anchor is not to be less than 60 per cent of the total weight of the anchor.
- 3409 When stocked bower or stream anchors are to be used, the weight "ex stock" is to be not less than 80 per cent of the Table weight for ordinary stockless bower anchors. The weight of the stock is to be 25 per cent of the total weight of the anchor, including the shackle, etc., but excluding the stock.
- 3410 When anchors of a design approved for the designation "High Holding Power Anchor" are used as bower anchors, the weight of each such anchor may be 75 per cent of the Table weight for ordinary stockless bower anchors.

Anchor Design

- 3411 Anchors are to be of approved design. The design of all anchor heads is to be such as to minimize stress concentrations and, in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.
- 3412 For approval as a "High Holding Power" anchor, satisfactory tests are to be made on various types of bottom, and the anchor is to have a holding power at least twice that of an "Admiralty Standard Stockless" anchor of the same weight.

Chain Cables

- 3413 Chain cables may be of wrought iron, mild steel, special quality steel or extra special quality steel in accordance with the requirements of P 8.
- 3414 Chain cables are to be graded as follows (see also P 801).
- **3415** Grades 1 (a), 1 (b) or U 1 (a) materials are not to be used in association with high holding power anchors.

Grade U 3 material is only to be used for chain $40 \text{ mm} (1\frac{9}{16} \text{ in})$ or more in diameter.

GRADE	MATERIAL	U.T.S. KG/MM ² (TON/IN ²)
1(a) 1(b) U 1(a)	Wrought iron Mild steel Mild steel	Exceeding 31 (19·7) but not exceeding 41 (26)
U 1(b)	Mild steel	Exceeding 41 (26) but not exceeding 50 (31·7)
U 2(a)	Special Quality steel	Exceeding 50 (31·7) but not exceeding 65 (41·3)
U 2(b)	Special Quality cast steel	Exceeding 50 (31·7) but not exceeding 70 (44·4)
U 3	Extra Special Quality steel	Exceeding 70 (44·4)

- 3416 When stream anchors are used in association with chain cable, this cable may be either stud link or short link.
- 3417 The form and proportion of links and shackles are to be in accordance with recognized practice.

Stream Wires, Towlines and Mooring Lines

3418 Towlines and mooring lines may be of wire, natural fibre or synthetic fibre material, or of a mixture of wire and either natural or synthetic fibre. The diameter, construction and specification of wire or natural fibre towlines and mooring lines are to comply with the requirements P 9 and P 10.

Where it is proposed to use synthetic fibre ropes the size and construction will be specially considered.

3419 The lengths of individual mooring lines may be reduced by up to 7 per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length.

Testing of Equipment

- 3420 All anchors and chain cables are to be tested at establishments and on machines recognized by the Committee under the supervision of the Society's Surveyors or other Officer recognized by the Committee, and in accordance with P 7 and P 8.
- 3421 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the anchors and cables are placed on board the ship.
- 3422 Steel wire and fibre ropes are to be tested as required by P 9 and P 10.

Arrangements for Working and Stowing Anchors and Cables

3423 A windlass of sufficient power and suitable for the size of chain cable is to be fitted and efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased and adequate stiffening is to be provided, to the Surveyor's satisfaction.

3424 An easy lead of the cables from the windlass to the anchors and chain locker is to be arranged.

3425 Hawse pipes are to be of ample thickness and of a suitable size and form to house the anchors efficiently. Substantial chafing lips are to be provided at the shell and

deck. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary.

3426 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker, and provision is to be made for securing the inboard ends of the cables to the structure.

3427 Satisfactory arrangements are to be made for the stowage and working of the stream anchor if provided.

15th July, 1971

LLOYD'S REGISTER OF SHIPPING

TABLE D 34.1-EQUIPMENT

EQUIPMEN (See D	7 NUMBER 3403)		Bower	ANCHORS		St	BOWER	AIN CABLES F ANCHORS	OR		WIRE OR	To	WLINE	1	Mooring Li	NES
Exceeding	Not Exceeding	EQUIP- MENT LETTER	Number	Weight per Anchor	STOCKLESS STREAM ANCHOR	Total Length	Mild Steel (Grade 1 or U 1)	Special Quality Steel (Grade U2)	Extra Special Quality Steel (Grade U 3)	Minimum Length	Minimum Breaking Strength	Minimum Length	Minimum Breaking Strength	Number	Minimum Length of each Line	Minimu Breakir Strengt
50 70 90	70 90 110	A B C	2 2 2 2	180 240 300	60 80 100	220 220 247,5	mm 14 16 17,5	mm 12,5 14 16	mm _ _	80 85 85	kg 6600 7500 8300	180 180 180 180	kg 10 000 10 000 10 000	2 2 2 2	100 100 110	3500 3750 4000
110 130 150	130 150 175	D E F	2 2 2	360 420 480	120 140 165	247,5 275 275	19 20,5 22	17,5 17,5 19	=	90 90 90	9100 10 000 11 000	180 180 180	10 000 10 000 10 000	2 2 2	110 120 120	4500 5000 5550
175 205 240	205 240 280	G H I	2 3 3	570 660 780	190 	302,5 302,5 330	24 26 28	20,5 22 24	=	90	12 000	180 180 180	11 400 13 200 15 300	2 2 3	120 120 120	6000 6550 7250
280 320 360	320 360 400	J K L	3 3 3	900 1020 1140		357,5 357,5 385	30 32 34	26 28 30			=	180 180 180	17 700 21 100 22 800	3 3 3	140 140 140	8000 8750 9500
400 450 500	450 500 550	M N O	3 3 3	1290 1440 1590	=	385 412,5 412,5	36 38 40	32 34 34		-	=	180 180 190	25 500 28 200 31 200	3 3 4	140 140 160	10 250 11 000 11 500
550 600 660	600 660 720	P Q R	3 3 3	1740 1920 2100	=	440 440 440	42 44 46	36 38 40	_	=	_	190 190 190	34 500 37 800 41 400	4 4 4	160 160 160	12 000 12 500 13 000
720 780 840	780 840 910	S T U	3 3 3	2280 2460 2640		467,5 467,5 467,5	48 50 52	42 44 46	<u>-</u>	=	Ξ	190 190 190	45 000 48 900 52 800	4 4 4	170 170 170	13 500 14 000 14 500
910 980 1060	980 1060 1140	V W X	3 3 3	2850 3060 3300		495 495 495	54 56 58	48 50 50	42 44 46			190 200 200	57 000 61 500 66 000	4 4 4	170 180 180	15 000 16 000 17 000
1140 1220 1300	1220 1300 1390	Y Z A†	3 3 3	3540 3780 4050	=	522,5 522,5 522,5	60 62 64	52 54 56	46 48 50			200 200 200	70 500 75 300 80 100	4 4 4	180 180 180	18 000 19 000 20 000
1390 1480 1570	1480 1570 1670	B† ~ C† D†	3 3 3	4320 4590 4890	=	550 550 550	66 68 70	58 60 62	50 52 54	Ξ	=	200 220 220	85 200 90 600 96 000	4 5 5	180 190 190	21 000 22 000 23 000
1670 1790 1930	1790 1930 2080	E† F† G†	3 3 3	5250 5610 6000		577,5 577,5 577,5	73 76 78	64 66 68	56 58 60	Ξ	Ξ	220 220 220	104 400 113 100 119 100	5 5 5	190 190 190	24 000 25 000 26 000
2080 2230 2380	2230 2380 2530	H† I† J†	3 3 3	6450 6900 7350		605 605 605	81 84 87	70 73 76	62 64 66	=	Ξ	240 240 240	128 400 138 300 148 200	5 5 5	200 200 200	27 000 28 000 29 000
2530 2700 2870	2700 2870 3040	K† L† M†	3 3 3	7800 8300 8700		632,5 632,5 632,5	90 92 95	78 81 84	68 70 73	Ξ	=	260 260 260	150 000 150 000 150 000	6 6 6	200 200 200	30 000 31 000 32 000
3040 3210 3400	3210 3400 3600	N† O† P†	3 3 3	9300 9900 10 500	=	660 660 660	97 100 102	84 87 90	76 78 78	E		280 280 280	150 000 150 000 150 000	6 6 6	200 200 200	33 000 34 000 35 000
3600 3800 4000	3800 4000 4200	Q† R† S†	3 3 3	11 100 11 700 12 300	=	687,5 687,5 687,5	105 107 111	92 95 97	81 84 87	Ξ		300 300 300	150 000 150 000 150 000	6 6 7	200 200 200	36 000 37 000 38 000
4200 4400 4600	4400 4600 4800	T† U† V†	3 3 3	12 900 13 500 14 100	=	715 715 715	114 117 120	100 102 105	87 90 92	Ē	=	300 300 300	150 000 150 000 150 000	7 7 7	200 200 200	39 00 40 00 41 00
4800 5000 5200	5000 5200 5500	W† X† Y†	3 3 3	14 700 15 400 16 100	=	742,5 742,5 742,5	122 124 127	107 111 111	95 97 97	=		300 300 300	150 000 150 000 150 000	7 8 8	200 200 200	42 00 44 00 46 00
5500 5800 6100	5800 6100 6500	Z† A* B*	3 3 3	16 900 17 800 18 800	=	742,5 742,5 742,5	130 132 —	114 117 120	100 102 107		=	300 300	150 000 150 000	8 8 9	200 200 200	48 00 50 00 50 00
6500 6900 7400	6900 7400 7900	E*	3 3 3	20 000 21 500 23 000		770 770 770	Ξ	124 127 132	111 114 117		=	is not	A towline is not required when the ship's length L exceeds 90 m		200 200 200	50 00 50 00 50 00
7900 8400 8900 9400	8400 8900 9400 10 000	F* G* H* I*	3 3 3 3	24 500 26 000 27 500 29 000	Ē	770 770 770 770 770	=	137 142 147 152	122 127 132 132	=	=	A towline			200 200 200 200 200	50 00 50 00 50 00 50 00

NOTES-TABLE D 34.1

- 1. A towline is not required when the ship's length L exceeds 90 m.
- 2. The rope used for stream wire is to be constructed of not less than 72 wires made up into six strands.
- 3. Wire ropes used for towlines and mooring lines are generally to be of flexible construction with not less than:—

144 wires in 6 strands with 7 fibre cores for strengths up to 50 000 kg,

222 wires in 6 strands with 1 fibre core for strengths exceeding $50\ 000\ kg.$

The wires laid round the fibre centre of each strand are to be made up in not less than two layers.

- 4. Wire ropes for towlines and mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction, preferably with not less than 186 wires in 6 strands over an independent wire rope core.
- 5. Irrespective of strength requirements, no fibre rope is to be less than 20 mm diameter.
- 6. For permitted variations in anchor weights, see D 3407 and D 3410.
 - 7. Tests. See P 7 for anchors.

P 8 for chain cables.

P 9 for wire ropes.

P 10 for fibre ropes.

Chapter D

Chapter D

LLOYD'S REGISTER OF SHIPPING

TABLE D 34.1—EQUIPMENT

or in British units:—

EQUIPMENT (See D			STOC BOWER	KLESS ANCHORS		St		AIN CABLES FO ANCHORS	OR		WIRE OR AIN	Tow	LINE	1	MOORING LIN	ies
Exceeding	Not Exceeding	EQUIP- MENT LETTER	Number	Weight per Anchor	STOCKLESS STREAM ANCHOR	Total Number of 15 Fathom Lengths	Mild Steel (Grade 1 or U 1)	Special Quality Steel (Grade U 2)	Extra Special Quality Steel (Grade U 3)	Minimum Length	Minimum Breaking Strength	Minimum Length	Minimum Breaking Strength	Number	Minimum Length of each Line	Minimum Breaking Strength
50 70 90	70 90 110	A B C	2 2 2 2	cwt $3\frac{1}{2}$ $4\frac{3}{8}$ $5\frac{7}{8}$	$1\frac{1}{8}$ $1\frac{5}{8}$ 2	8 8 9	inches 9 16 5 8 11 16	inches	inches	fms 44 46 46	tons 6.50 7.38 8.17	fms 98 98 98	tons 9 · 84 9 · 84 9 · 84	2 2 2	fms 55 55 60	3 · 44 3 · 69 3 · 94
110 130 150	130 150 175	D E F	2 2 2	$7\frac{1}{8}$ $8\frac{1}{4}$ $9\frac{1}{2}$	23 23 34	9 10 10	3 4 13 16 7 8	11 10 11 10 3 4	=	49 49 49	- 8-96 9-84 10-83	98 98 98	9·84 9·84 9·84	2 2 2	60 66 66	4·43 4·92 5·46
175 205 240	205 240 280	G H I	2 3 3	$\begin{array}{c} 11\frac{1}{4} \\ 13 \\ 15\frac{3}{8} \end{array}$	33	11 11 12	1 1 1½	13 16 7 8 15 16	=	49	11.81	98 98 98	11·22 12·99 15·06	2 2 3	66 66 66	5·90 6·45 7·13
280 320 360	320 360 400	J K L	3 3 3	$\begin{array}{c} 17\frac{3}{4} \\ 20 \\ 22\frac{1}{2} \end{array}$	E	13 13 14	$1\frac{3}{16}$ $1\frac{1}{4}$ $1\frac{5}{16}$	$\begin{array}{c} 1 \\ 1\frac{1}{8} \\ 1\frac{3}{16} \end{array}$				98 98 98	17·42 20·77 22·44	3 3 3	77 77 77	7·87 8·61 9·35
400 450 500	450 500 550	M N O	3 3 3	$\begin{array}{c} 25\frac{3}{8} \\ 28\frac{3}{8} \\ 31\frac{1}{4} \end{array}$	3	14 15 15	$\begin{array}{c} 1_{\overline{16}}^{-7} \\ 1_{\overline{2}}^{1} \\ 1_{\overline{16}}^{-9} \end{array}$	$\begin{array}{c} 1\frac{1}{4} \\ 1\frac{5}{16} \\ 1\frac{5}{16} \end{array}$	Ξ	Ξ	II.	98 98 104	$25 \cdot 10$ $27 \cdot 75$ $30 \cdot 71$	3 3 4	77 77 87	10·09 10·83 11·32
550 600 660	600 660 720	P Q R	3 3 3	34¼ 37¾ 41¾		16 16 16	$\begin{array}{c} 1\frac{5}{8} \\ 1\frac{3}{4} \\ 1\frac{13}{16} \end{array}$	$\begin{array}{c} 1_{\frac{7}{16}} \\ 1_{\frac{1}{2}} \\ 1_{\frac{9}{16}} \end{array}$				104 104 104	33 · 95 37 · 20 40 · 75	4 4 4	87 87 87	11.81 12.30 12.79
720 780 840	780 840 910	S T U	3 3 3	$\begin{array}{c} 44\frac{7}{8} \\ 48\frac{1}{2} \\ 52 \end{array}$	Ē	17 17 17	$\begin{array}{c} 1\frac{7}{8} \\ 2 \\ 2\frac{1}{16} \end{array}$	$\begin{array}{c} 1\frac{5}{8} \\ 1\frac{3}{4} \\ 1\frac{13}{16} \end{array}$	1 9 10		=	104 104 104	44 · 29 48 · 13 51 · 97	4 4 4	93 93 93	13·29 13·78 14·27
910 980 1060	980 1060 1140	W X	3 3 3	56\\\ 60\\\\ 65		18 18 18	$\begin{array}{c} 2\frac{1}{8} \\ 2\frac{3}{16} \\ 2\frac{5}{16} \end{array}$	178 2 2 2	$\begin{array}{c} 1\frac{5}{8} \\ 1\frac{3}{4} \\ 1\frac{13}{16} \end{array}$			104 109 109	56·10 60·53 64·96	4 4 4	93 98 98	14·76 15·75 16·73
1140 1220 1300	1220 1300 1390	Y Z A†	3 3 3	69 3 74 8 79 3		19 19 19	$\begin{array}{c} 2\frac{3}{8} \\ 2\frac{7}{16} \\ 2\frac{1}{2} \end{array}$	$\begin{array}{c} 2\frac{1}{16} \\ 2\frac{1}{8} \\ 2\frac{3}{16} \end{array}$	$\begin{array}{c} 1\frac{13}{16} \\ 1\frac{7}{8} \\ 2 \end{array}$		E	109 109 109	69·39 74·11 78·83	4 4 4	98 98 98	17·72 18·70 19·68
1390 1480 1570	1480 1570 1670	B† C† D†	3 3 3	85 90 [§] 96 [‡]		20 20 20	$2\frac{5}{8}$ $2\frac{11}{16}$ $2\frac{3}{4}$	$\begin{array}{c} 2\frac{5}{16} \\ 2\frac{3}{8} \\ 2\frac{7}{16} \end{array}$	2 2 10 2 10 2 18		=	109 120 120	83 · 95 89 · 17 94 · 48	4 5 5	98 104 104	20 · 67 21 · 65 22 · 64
1670 1790 1930	1790 1930 2080	E† F† G†	3 3 3	$103\frac{3}{8} \\ 110\frac{1}{2} \\ 118\frac{1}{8}$		21 21 21	$\frac{2^{7}_{8}}{3}$ $3^{\frac{1}{16}}$	$\begin{array}{c} 2\frac{1}{2} \\ 2\frac{5}{8} \\ 2\frac{11}{16} \end{array}$	$\begin{array}{c} 2\frac{3}{16} \\ 2\frac{5}{16} \\ 2\frac{3}{8} \end{array}$		ZE.	120 120 120	$\begin{array}{c} 102 \cdot 75 \\ 111 \cdot 31 \\ 117 \cdot 22 \end{array}$	5 5 5	104 104 104	23 · 62 24 · 60 25 · 59
2080 2230 2380	2230 2380 2530	H† I† J†	3 3 3	127 135% 144%	=	22 22 22 22	3 10 3 5 3 10 3 10	2 ³ / ₄ 2 ⁷ / ₈ 3	$\begin{array}{c} 2\frac{7}{16} \\ 2\frac{1}{2} \\ 2\frac{5}{8} \end{array}$		i iom a	131 131 131	126 · 37 136 · 11 145 · 86	5 5 5	109 109 109	26 · 57 27 · 56 28 · 54
2530 2700 2870	2700 2870 3040	K† L† M†	3 3 3	$153\frac{5}{8}$ $163\frac{1}{2}$ $171\frac{3}{8}$		23 23 23	3 9 3 16 3 8 3 3	3 1 3 3 3 3 3 3 3 5 3 5 10	2 11 2 3 2 7 2 7	=	=	142 142 142	147 · 63 147 · 63 147 · 63	6 6 6	109 109 109	29 · 53 30 · 51 31 · 49
3040 3210 3400	3210 3400 3600	N† O† P†	3 3 3	183½ 195 206¾	=	24 24 24 24	3 13 3 15 4	$\begin{array}{c} 3\frac{5}{10} \\ 3\frac{7}{16} \\ 3\frac{9}{16} \end{array}$	3 3 1 3 1 3 1 3 1 6	=		153 153 153	147 · 63 147 · 63 147 · 63	6 6 6	109 109 109	32 · 48 33 · 46 34 · 45
3600 3800 4000	3800 4000 4200	Q† R† S†	3 3 3	$\begin{array}{c} 218\frac{5}{8} \\ 230\frac{3}{8} \\ 242\frac{1}{4} \end{array}$	=	25 25 25	4½ 4¾ 4¾ 4¾	35 34 313 316	$\begin{array}{c} 3\frac{3}{16} \\ 3\frac{5}{16} \\ 3\frac{7}{16} \end{array}$	=	=	164 164 164	147 · 63 147 · 63 147 · 63	6 6 7	109 109 109	35 · 43 36 · 42 37 · 40
4200 4400 4600	4400 4600 4800	T† U† V†	3 3 3	254 265 7 277 8	Ē	26 26 26	4½ 4½ 4½ 4¾ 4¾	3 15 4 4 418	3 7 3 16 3 16 3 8	Ξ	Ē	164 164 164	147 · 63 147 · 63 147 · 63	7	109 109 109	38 · 38 39 · 37 40 · 38
4800 5000 5200	5000 5200 5500	W† X† Y†	3 3 3	289½ 303¾ 317¾	=	27 27 27	4-13- 47- 5	4 3 4 3 4 3 4 3 4 8	$\begin{array}{c} 3\frac{3}{4} \\ 3\frac{13}{16} \\ 3\frac{13}{16} \end{array}$	Ξ	Ξ	164 164 164	147 · 63 147 · 63 147 · 63	8	109 109 109	41 · 34 43 · 30 45 · 27
5500 5800 6100	5800 6100 6500	Z† A* B*	3 3 3	332½ 350½ 370½	=	27 27 27	5½ 5¾ 5¾	4½ 4½ 4½ 4¾	315 4 4 43 16	=	Ξ	164 164	147 · 63 147 · 63		109 109 109	47 · 24 49 · 20 49 · 20
6500 6900 7400	6900 7400 7900	E*	3 3 3	3937 4238 453	Ξ	28 28 28	=	4 ⁷ / ₈ 5 5 ₁₆	4 ³ / ₈ 4 ¹ / ₂ 4 ⁵ / ₈	Ξ	=	s not	th L	10 11 12	109 109 109	49·20 49·20 49·20
7900 8400 8900 9400	8400 8900 9400 10 000	F* G* H* I*	3 3 3 3	$\begin{array}{c} 482\frac{1}{2} \\ 512 \\ 541\frac{5}{8} \\ 571\frac{1}{8} \end{array}$	=	28 28 28 28	=	5 3 5 9 5 16 5 1 6	$\begin{array}{c} 4\frac{13}{16} \\ 5 \\ 5\frac{3}{56} \\ 5\frac{3}{16} \end{array}$	E	Ē	A towline i	ship's length L exceeds 295 ft	13 14 16 18	109 109 109 109	49 · 20 49 · 20 49 · 20 49 · 20

NOTES-TABLE D 34.1

- A towline is not required when the ship's length L exceeds 295 ft.
- 2. The rope used for stream wire is to be constructed of not less than 72 wires made up into six strands.
- 3. Wire ropes used for towlines and mooring lines are generally to be of flexible construction with not less than:—

144 wires in 6 strands with 7 fibre cores for strengths up to $49\cdot 21$ tons,

222 wires in 6 strands with 1 fibre core for strengths exceeding $49\cdot 21$ tons.

The wires laid round the fibre centre of each strand are to be made up in not less than two layers.

- 4. Wire ropes for towlines and mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction, preferably with not less than 186 wires in 6 strands over an independent wire rope core.
- 5. Irrespective of strength requirements, no fibre rope is to be less than $2\cdot 47$ inches circumference.
- 6. For permitted variations in anchor weights, see D 3407 and D 3410.
 - 7. Tests. See P 7 for anchors.
 - P 8 for chain cables.
 - P 9 for wire ropes.
 - P 10 for fibre ropes.

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TABLE D 34.2

RENEWAL OF STEERING CHAINS AND CHAIN CABLES WHEN WORN

When any length of a chain is so worn that the mean diameter at its most worn part is reduced to the size given in the following Table it is to be renewed:

ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL						
mm	mm	mm	mm	mm	mm	mm	mm
16	14,5	35	31	54	48,5	73	65
17	15,5	36	32	55	49,5	74	66
18	16	37	33	56	50	75	67
19	17	38	34	57	51	76	68
20	18	39	35 9 36	58	51,5	77	69
21	18,5	40	36	59	52,5	78	70
22	19,5	41	36,5	60	53,5	79	71
23	20,5	42	37,5	61	54,5	80	72
24	21,5	43	38,5	62	55,5	81	73
25	22,5	44	39,5	63	56,5	82	74
26	23	45	40	64	57,5	83	75
27	24	46	41	65	58	84	75,5
28	25	47	42	66	59	85	76
29	26	48	43	67	. 60	86	77
30	27	49	43,5	68	61	87	77,5
31	28	50	44,5	69	62	88	78,5
32	28,5	51	45,5	70	63	89	79,5
33	29,5	52	46,5	71	64	111-21 9	
34	30,5	53	47,5	72	64,5		1 10-1-1

or in British units:-

TABLE D 34.2

RENEWAL OF STEERING CHAINS AND CHAIN CABLES WHEN WORN

When any length of a chain is so worn that the mean diameter at its most worn part is reduced to the size given in the following Table it is to be renewed.

ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL	ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL	ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL	ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
3 8	1 1 3 2	1,5	1_{16}^{3}	$2\frac{1}{4}$	2	3,3	$2\frac{7}{8}$
7 6	1 3 3 2	13	1 372	$2\frac{5}{16}$	2,18	31	$2\frac{15}{16}$
$\frac{1}{2}$	7 1 6	1,7	1 3 2	23	$2\frac{t}{8}$	3,5	2^{31}_{32}
9 1 6	1/2	11/2	1 1 1 2	2,76	2 3	33	$3_{3\frac{1}{2}}^{-1}$
5	7 6	1 7 6	1133	$2\frac{1}{2}$	$2\frac{1}{4}$	3,7	3,1
1 1 1 6	5	1.5	1 1 5 2	$2_{1^{\frac{9}{6}}}$	2 3 2	31/2	31/8
$\frac{3}{4}$	2 1 3 2	1 1 1	11/2	2 5 8	$2\frac{1}{3}\frac{1}{2}$	3,9	3,3
1 3 1 6	2.3 3.2	$1\frac{3}{4}$	1, 9	2 1 1 6	$2^{\frac{1}{3}\frac{3}{2}}$	35	31
7 8	2 5 3 2	113	1 5	23	$2\frac{1}{3}\frac{5}{2}$	3 1	3,5
1 5 1 6	2.7 3.9	178	1116	213	217	$3\frac{3}{4}$	33
1	2 9 3 2	1 1 5	$1\frac{2}{3}\frac{3}{2}$	2 7	2,5	313	3,7
1,1,6	1 5 1 6	2	1 3 5	215	$2\frac{\pi}{8}$	3 ⁷ g	$3\frac{1}{2}$
$1\frac{1}{8}$	1	2,1,4	1 3 7	3	211		
1,3	1,16	21/8	1 3 9	3,1	$2\frac{3}{4}$		
11/4	118	2 3	131	31/8	213	no disposal lo-	- Harris 19

OIL TANKERS

Section 40

GENERAL

Application

4001 The following Rules apply to the Class 100Al Oil Tanker. (See B 103.) The scantlings and arrangements of tankers intended for cargoes other than petroleum will be specially considered in relation to the nature and density of the cargo.

Sections D 1 to D 34 apply to tankers except as otherwise required by the following Rules.

For scantling reductions when higher tensile steel complying with P 3 is used, see D 65.

Method of Construction

4002 The following Rules and Tables give requirements for welded construction with certain modifications when riveting is adopted.

Structural Design

4003 The Rules apply to single deck tankers over 90 m (295 ft) in length with machinery aft and having two or more longitudinal bulkheads.

The bottom and deck are to be framed longitudinally in the cargo tank spaces; the Rules assume longitudinal framing at the sides and longitudinal bulkheads where the length of the ship exceeds 200 m (656 ft), but alternative designs will be considered.

If the proportion of length to depth exceeds sixteen, or the ratio of breadth to depth exceeds 2:1, increased scantlings may be required.

4004 The length of a tank is not to exceed 0,2L. When the length exceeds 0,1L or 15 m (49 ft), whichever is the greater, a transverse wash bulkhead is to be fitted at about the mid-length of the tank.

4005 The scantlings of primary supporting structure such as transverses, girders, webs and stringers may be assessed using direct calculation. In such cases the calculations are to be submitted for approval.

Loading

4006 Any dry tanks, or tanks intended for water ballast only and thus empty in the loaded condition, are to be indicated on the plans submitted for approval and the arrangements are to be such that these tanks cannot be used for any other purpose.

4007 In order to guard against high stresses being imposed through an unsatisfactory cargo or ballast loading it is recommended that tankers be supplied with an approved instrument for determining suitable loading.

Grades of Steel

4008 Where the seams and butts are welded, steel of Grades B and D (see Table P 2.2) will generally be required for the parts of the structure as detailed in Table D 40.1.

4009 In general, strakes of Grade E steel are to be arranged as in Table D 40.2.

The fore and aft extent of the Grade E strakes is to be as follows:—

- (a) Sheerstrake and deck plating from within the poop to 0,2L forward of amidships.
- (b) Bottom and bilge plating for 0,4L amidships.

The breadth of each strake is not to be less than 1525 mm (60 in), except that the bilge strake shall not be less than 1835 mm (72 in).

Cofferdams and Below Deck Passages or Tunnels

4010 Cofferdams are to be provided at the forward and after ends of the oil cargo spaces; cofferdams are to be at least 760 mm (30 in) in length and are to cover the whole area of the end bulkheads of the cargo spaces.

Pump rooms or water ballast tanks will be accepted in lieu of a cofferdam. An oil fuel bunker will also be accepted provided the bulkhead between it and the cargo tank is completely welded.

Where a compartment or tank such as a fore peak tank forms the forward cofferdam, access is to be from the open deck. Alternatively, the space containing the access must conform to the requirements of M 16. Diesel or electrically driven pumps should not be sited in the space containing the access. (The attention of the Owners should be drawn to the Suez Canal Authority's requirement that only pump rooms or water ballast tanks can be accepted in lieu of a cofferdam.)

TABLE D 40.1

AMIDSHIPS Sheerstrake Strength deck stringer Bottom shell to upper turn of bilge* Top and bottom strake of longitudinal bulkhead Longitudinals of slab type cut from plates on:— (i) Deck and bottom shell (ii) Side shell and longitudinal bulkheads for 0,1D from deck and bottom Through brackets for deck and bottom longitudinals and also for longitudinals on side shell and longitudinal bulkheads for 0,1D from deck and bottom		GRADES OF PLATING		
		Thickness greater than 20,5 mm (0·8 in) but not exceeding 25,5 mm (1·0 in)	Thickness greater than 25,5 mm (1·0 in)	EXTENT
		В	D	When L = 155 m (508 ft) and below for 0,3L amid- ships When L = 215 m (705 ft) and above for 0,4L amid- ships Intermediate values by interpolation When L = 215 m (705 ft) and above for 0,4L amid- ships ships Intermediate values by interpolation
Webs of deck and bottom longitudinals and girders}			$\begin{cases} B \\ D \text{ if over 35,5 mm} \\ (1 \cdot 4 \text{ in}) \end{cases}$	or annual transfer of the second of the seco
Face flats of deck and bottom longitudinals and girders			D if over 35,5 mm (1.4 in)	
Sheerstrake Strength deck stringer Strength deck plating	In way of poop front	В	D	Extended forward to cover any pump room openings
Strength deck plating Bottom shell plating to upper turn of bilge	Between after limit of amidships portion and 0,25L aft of amidships		D	
Sheerstrake Strength deck stringer Elsewhere		-	D	
Keel plate is to be same Gra bottom shell plating				

TABLE D 40.2

LENGTH L			
Over	Not exceeding	GRADE E STRAKES	
Metres (Feet) 215 (705)	Metres (Feet) 230 (754)	}Bilge strake	
230 (754)	245 (803)	Bilge strake Sheerstrake	
245 (803)	260 (852)	Bilge strake Sheerstrake Bottom strake in way of longitudina bulkhead	
260 (852)		As for tankers over 245 m (803 ft) with the addition of the keel, see Note The deck strake in way of the longitudinal bulkhead is also to be Grade Funless the top strake of the bulkhead is Grade D	

Note. Where no continuous centreline girder is fitted, the keel may be Grade D, provided the bottom plating is Grade D

A cofferdam is also to be arranged between a cargo oil tank and accommodation spaces or between a cargo oil tank and spaces containing electrical equipment other than spaces where the only electrical equipment is lighting fittings complying with M 1604. (See also M 1605.) Where the bridge 'tween deck acts as a cofferdam any access to this 'tween deck from the deck above is to be from the open deck.

Passages or tunnels passing through, or adjacent to, a cargo oil tank and not separated from it by a cofferdam are to be provided with mechanical ventilation, and any access is to be from the open deck.

Freeing Arrangements and Gangway

4011 Ships with bulwarks are to have open rails fitted for at least half the length of the exposed part of each well.

A strong permanent fore and aft gangway is to be fitted at the level of the superstructure decks. Where there is no accommodation forward, the gangway between the bridge and forecastle may be omitted and where there is no midship erection and all accommodation, etc., is aft, the gangway may be omitted entirely. Arrangements are, however, to be made to give safe access to the fore end of the ship.

Submission of Plans

4012 In addition to the plans required by D 109, plans showing the construction of the transverse and longitudinal oiltight bulkheads, end connections for all longitudinals and other framing members, the structure at the ends of the

ship, deckhouses protecting machinery casings and arrangements at the junction of transverse and longitudinal framing are also to be submitted.

A plan showing the arrangement and sequence of erection of the fabrication units is to be submitted.

4013 The information required by D 41 is to be forwarded when the midship section is submitted.

Anodes in Tanks

4014 When anodes are fitted in tanks they are to be of approved design and securely attached to the structure, both initially and during service. A plan showing the details of design and attachment and the location of the anodes is to be submitted.

Magnesium anodes are only permitted in tanks intended solely for water ballast.

Fittings in Tanks

4015 Ladders, pipe hangers and other fittings in the cargo tanks and pump rooms are to be securely fastened to the structure.

Corrosion Control

4016 When an approved system of corrosion control is installed the reduction in thickness given in Table D 40.3 will be allowed. Where reductions are desired at the top of

TABLE D 40.3

ITEM	PERMISSIBLE REDUCTION 1N THICKNESS
Plating and stiffeners of transverse and longitudinal bulkheads. Bottom, side and deck transverses. Transverse side framing. Vertical webs and horizontal girders. Cross ties.	10 per cent
Keel. Bottom and side shell. Deck plating. Bottom, side and deck longitudinals. Bottom and deck centreline and side girders.	5 per cent

the tank within 1,525 m (5 ft) of the deck at side, this part of the tank is to be coated but other approved systems may be used for the remainder of the tank.

When reductions have been effected a notation will be made in the Register Book.

The minimum thickness of keel, bottom and deck plating given in D 4303, D 4302 and D 4202 respectively may be reduced by 5 per cent. The minimum thickness of the remaining items may be 1,0 mm (0.04 in) less than the minimum given in D 5309.

Special consideration will be given to the extent of protection required in tankers intended solely for the carriage of crude oil.

The plans of midship section, profile and decks and shell expansion should indicate both the Rule scantlings and the thicknesses proposed.

Section 41

LONGITUDINAL STRENGTH

4101 The section modulus is not to be less than the greater of the following values:-

(b)
$$\frac{\text{M}}{3} + 104 \text{ SWBM cm}^3$$
 $\left(\frac{\text{M}}{3} + \frac{\text{SWBM}}{6 \cdot 1} \text{ in}^2 \text{ft}\right)$

where M = f K B (C_b + 0,70)
$$\times$$
 10⁵ cm³
(M = f K B (C_b + 0.70) \times 10³ in² ft)

f is as follows:-

7340		f .
Length L	Deck	Keel
up to 100 m (328 ft)	0,93	0,96
300 m (984 ft) and above	0,90	0,90

Intermediate values to be determined by interpolation

K is to be determined from Table D 41.1,

Cb is the moulded block coefficient at load draught. Where the block coefficient is less than 0,75, a value equal to $\left(\frac{C_b + 0,75}{2}\right)$ be used. The block coefficient is to be determined using the length L as defined in D 201,

B is the moulded breadth, in metres (feet),

SWBM is the maximum still water bending moment, in tonnes metres (tons feet), hogging or sagging (see 4102 and 4103).

NOTES

When the required section modulus is the minimum acceptable, i.e. that given by (a) above, the maximum associated still water bending moment will be 6,4 (keel modulus) $\times 10^{-3}$ tonne m (4·08 (keel modulus) ton ft) which corresponds to a stress of 6,4 kg/mm² (4·08 ton/in²). The section modulus calculated by (b) above should be based upon the f value for the keel. The deck modulus/keel modulus ratio should be the same as the ratio of the f values appropriate to the length.

4102 The still water bending moment is to be calculated for the homogeneous loaded condition (excluding dry tanks and tanks used solely for water ballast) and for the ballast or part loaded conditions (departure and arrival). The calculations are to be submitted.

4103 Where in loaded, ballast or part loaded conditions the load is not uniformly distributed over the cargo tank length, curves of still water bending moment and shear force are to be submitted. The method of calculating these curves is to be submitted together with the assumed longitudinal distribution of lightship weight.

4104 When the still water bending moment is required to be calculated for conditions other than homogeneous load conditions, the approved loading is to be incorporated in the Loading Manual.

Midship Modulus Calculation

4105 The section modulus calculation is to be forwarded with the midship section.

The calculation of the inertia of the midship section modulus is to include all continuous longitudinal material, and the lever "y" is to be measured from the neutral axis to the top of the keel and to the moulded deck line at side.

4106 Elliptical deck openings need not be deducted, provided their major axes are fore and aft, the ratio of the length to breadth of each opening is not less than 2:1 and the total breadth of such openings in a transverse section does not exceed 0,06B.

4107 Lightening holes in girders need not be deducted, provided their depth does not exceed 20 per cent of the depth of the girder web.

Where longitudinals are scalloped, the net area in way of scallop is to be used. Isolated drain holes need not be deducted, but compensation will be required for large drain holes at the bulkheads.

TABLE D 41.1—VALUES OF K

L	К	Difference in K per 5 m difference in L	LENGTH	K	Difference in K per 5 m difference in L	LENGTH	К	Difference in K per 5 m difference in L
Metres		eatherd may the	Metres		0,255	Metres		0,380
90	0,747	0,118	195	4,329	0,265	300	11,437	0,385
95	0,865		200	4,594		305	11,822	
100	0.005	0,120	205	1 000	0,274	240	10 010	0,391
100	0,985	0,121	200	4,868	0,282	310	12,213	0,397
105	1,106		210	5,150		315	12,610	
110	1,228	0,122	215	5,440	0,290	320	13,013	0,403
		0,123		The same of the sa	0,299		A contract of the contract	0,410
115	1,351	0,125	220	5,739	0,308	325	13,423	0,416
120	1,476		225	6,047		330	13,839	
125	1,606	0,130	230	6,364	0,317	335	14,262	0,423
120	1,000	0,138	400	0,001	0,326	000	14,202	0,429
130	1,744	0.147	235	6,690	0.225	340	14,691	0.495
135	1,891	0,147	240	7,025	0,335	345	15,126	0,435
		0,155	045	The state of the s	0,344	050		0,442
140	2,046	0,164	245	7,369	0,353	350	15,568	0,448
145	2,210		250	7,722		355	16,016	
150	2,382	0,172	255	8,083	0,361	360	16,470	0,454
		0,181			0,365			0,461
155	2,563	0,189	260	8,448	0,368	365	16,931	0,467
160	2,752	STEEL STREET	265	8,816		370	17,398	0,101
165	2,950	0,198	270	9,186	0,370	375	17,871	0,473
100		0,207			0,372	010	11,011	0,480
170	3,157	0,215	275	9,558	0,373	380	18,351	0,486
175	3,372		280	9,931	The state of the s	385	18,837	0,400
100	9 500	0,224	905	10 205	0,374	200		0,492
180	3,596	0,234	285	10,305	0,375	390	19,339	0,499
185	3,830		290	10,680		395	19,828	0.505
190	4,074	0,244	295	11,057	0,377	400	20,333	0,505
4,709)		0,255			0,380	11 11 11	11-1-11	

TABLE D 41.1—VALUES OF K

L	K	Difference in K per 1 ft difference in L	LENGTH L	K	Difference in K per 1 ft difference in L	LENGTH	K	Difference in K per 1 ft difference in L
Feet			Feet	5 1222	0.0024	Feet	12 202	0.0036
300	0.121	0.0011	640	0.672	0.0025	980	1.757	0.0036
310	0.132		650	0.697		990	1.793	
320	0.143	0.0011	660	0.723	0.0026	1000	1.830	0.0037
330	0.154	0.0011	670	0.749	0.0026	1010	1.867	0.0037
		0.0011			0.0027	1020	1.904	0.0037
340	0.165	0.0012	680	0.776	0.0027			0.0037
350	0.177	0.0012	690	0.803	0.0028	1030	1.941	0.0038
360	0.189	0.0012	700	0.831	0.0028	1040	1.979	0.0038
370	0.201		710	0.859		1050	2.017	
380	0.213	0.0012	720	0.887	0.0028	1060	2.056	0.0039
390	0.225	0.0012	730	0.916	0.0029	1070	2.095	0.0039
		0.0012			0.0029			0.0039
400	0.237	0.0012	740	0.945	0.0030	1080	2.134	0.0040
410	0.249	0.0013	750	0.975	0.0030	1090	2.174	0.0040
420	0.262		760	1.005		1100	2.214	
430	0.275	0.0013	770	1.036	0.0031	1110	2.254	0.0040
440	0.289	0.0014	780	1.067	0.0031	1120	2 · 295	0.0041
		0.0014			0.0032			0.0041
450	0.303	0.0015	790	1.099	0.0032	1130	2.336	0.0042
460	0.318	0.0016	800	1.131	0.0033	1140	2.378	0.0042
470	0.334		810	1.164		1150	2.420	
480	0.350	0.0016	820	1.197	0.0033	1160	2.462	0.0042
490	0.366	0.0016	830	1.231	0.0034	1170	2.505	0.0043
100000		0.0017			0.0034		777.7933	0.0043
500	0.383	0.0017	840	1.265	0.0034	1180	2.548	0.0043
510	0.400	0.0018	850	1.299	0.0035	1190	2.591	0.0044
520	0.418		860	1.334		1200	2.635	
530	0.437	0.0019	870	1.369	0.0035	1210	2.679	0.0044
540	0.456	0.0019	880	1.404	0.0035	1220	2.723	0.0044
		0.0020			0.0035			0.0045
550	0.476	0.0020	890	1.439	0.0035	1230	2.768	0.0045
560	0.496	0.0020	900	1.474	0.0035	1240	2.813	0.0046
570	0.516		910	1.509		1250	2.859	0.0046
580	0.537	0.0021	920	1.544	0.0035	1260	2.905	
590	0.558	0.0021	930	1.579	0.0035	1270	2.951	0.0046
		0.0022			0.0035			0.0047
600	0.580	0.0022	940	1.614	0.0035	1280	2.998	0.0047
610	0.602	0.0023	950	1.649	0.0036	1290	3.045	0.0047
620	0.625		960	1.685		1300	3.092	0.0048
630	0.648	0.0023	970	1.721	0.0036	1310	3.140	0.0048

Section 42

DECKS

Symbols

4201

L = length of ship, in metres (feet),

L₁ = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft),

B = moulded breadth, in metres (feet),

d = moulded draught, in metres (feet), but is not to be taken as less than 0,05L,

S = spacing of longitudinals, in mm (in).

Strength Deck

4202 The thickness of deck plating amidships is to be that necessary to give the section modulus required by D 4101, but is not to be less than:—

$$t = \frac{s}{3570} \left(L_1 + 75 \right) \sqrt{\frac{d}{L_1}} \ mm$$

$$\left(\ t = \frac{s}{11 \cdot 7} \left(\frac{\mathsf{L_1} + 246}{1000}\right) \sqrt{\frac{\mathsf{d}}{\mathsf{L_1}}} \ \mathrm{in} \right)$$

The midship thickness is to be maintained for 0,4L amidships and is to be gradually tapered to the end thickness. The midship thickness may be required over an increased extent if shown to be necessary by the bending moment curves.

4203 The thickness at the poop front is to extend into the poop for a distance at least equal to one-third the breadth B.

Where the machinery opening extends forward beyond a point one-third of the breadth B abaft the poop front, and the width of the casing exceeds one-half the breadth of the ship at the poop front, the thickness of deck plating may require to be increased. The forward corners of the casing opening are to be well rounded.

4204 The thickness of the stringer plate at the ends of the bridge is to be increased by 20 per cent.

If the poop front extends within 0,25L from amidships the stringer plate at the break is to be increased by 20 per cent. No increase is required if the poop front is 0,3L from amidships or greater. The increase at intermediate lengths is to be obtained by interpolation and is to be applied to the tapered thickness of the stringer plate.

The increase in thickness need not exceed 5 mm (0.20 in).

End Thickness

4205 The thickness of the deck stringer and plating for 0,05L at the fore end and 0,1L at the aft end is not to

be less than 6,0 +
$$\frac{L}{48}$$
 mm $\left(0.235 + \frac{L}{4000} \text{ in}\right)$

4206 If a stringer angle is fitted, in way of the cargo tanks and for at least one-third of the breadth B within the poop, it is to have 150 mm (6 in) flanges when the length L does not exceed 137 m (450 ft), 180 mm (7 in), flanges for lengths exceeding 137 m (450 ft) and not exceeding 167,5 m (550 ft) and 200 mm (8 in) flanges above 170 m (560 ft). The thickness is to be that of the sheerstrake or stringer whichever is less. Alternative riveted connections will be specially considered.

If the stringer angle is cut at the scuppers, compensation is to be provided. See also D 4311.

4207 Where a rounded sheerstrake is incorporated the radius should, in general, not be less than 15 times the thickness. The radius should be made by careful cold rolling or bending. Where grade E plates are subjected to severe cold working or where local heating of the plates is adopted, the plates may require to be re-normalized.

4208 The corners of all deck openings are to be well rounded and smooth, and strength is to be maintained in way of pump room entrances or other openings but compensation will not, in general, be required for small elliptical openings (see D 4106) nor forward of 0,2L forward of amidships nor abaft the poop front bulkhead. It is recommended that compensation for deck openings should be in the form of an increased thickness of plating, but alternative methods will be specially considered.

Lower Decks

4209 The scantlings and arrangements of lower decks are to be as required by D 4, D 6, D 8, D 13 and D 14.

4210 Abrupt discontinuities at the ends of lower decks and flats are to be avoided by suitable tapering of the stringer plates or by fitting large brackets.

Section 43

SHELL PLATING

Symbols

4301

L = length of ship, in metres (feet),

L₁ = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft),

B = moulded breadth, in metres (feet),

D = moulded depth, in metres (feet), to deck at side amidships,

d = moulded draught, in metres (feet),

S = spacing of frames or longitudinals, in mm (in).

Bottom Shell and Keel

4302 The thickness of bottom shell plating amidships is to be that necessary to give the section modulus required by D 4101, but is not to be less than:—

$$t = \frac{s}{3000} \left(L_1 + 75 \right) \sqrt{\frac{d}{L_1}} \ \mathrm{mm}$$

$$\left(\ t = \frac{\text{S}}{9.84} \left(\frac{\text{L}_1 + 246}{1000}\right) \sqrt{\frac{\text{d}}{\text{L}_1}} \ \text{in} \right)$$

d is not to be taken as less than 0,05L.

The midship thickness is to be maintained for 0,4L amidships and is to be gradually tapered to the end thickness. The midship thickness may be required over an increased extent if shown to be necessary by the bending moment curves.

4303 The width and thickness of the keel over the whole length are not to be less than the values derived from the following formulæ, nor is the thickness to be less than that of the adjacent shell plating.

Width = 70B mm (0.84B in) but need not exceed 1800 mm (71 in).

$$\mbox{Thickness} = 6 + \frac{\mbox{L}_{1}}{10} \ \mbox{mm} \qquad \left(0 \cdot 235 + \frac{12 \mbox{L}_{1}}{10\,000} \mbox{ in}\right)$$

Bilge Plating

4304 The thickness of the bilge plating is not to be less than that determined from 4302 using an equivalent spacing S₁:—

$$s_1 = Kl \text{ mm (in)}$$

where K = 1,06
$$-$$
 0,39 $\frac{l}{R}$, but need not exceed 1,0.

 S_1 is to be calculated for each panel of bilge plating (using values of l and R determined as given below) and the greatest value is to be used.

(a) Between adjacent longitudinals within the bilge:-

R = r mm (in),

 $\ell={
m distance}$ between adjacent longitudinals, in mm (in).

(b) Between lowest side longitudinal and top bilge longitudinal:—

$$R = \frac{r}{1 - \left(\frac{b - r}{\ell}\right)} \text{ mm (in)},$$

l = distance between lowest side longitudinal and top bilge longitudinal, in mm (in).

(c) Between outboard bottom longitudinal and lowest bilge longitudinal:—

$$R = \frac{r}{1 - \left(\frac{a - r}{l}\right)} \text{ mm (in)},$$

l = distance between outboard bottom longitudinal and lowest bilge longitudinal, in mm (in).

In (a), (b) and (c) above

r = radius of bilge, in mm (in),

 a = horizontal distance between ship's side and outboard bottom longitudinal, in mm (in),

b = vertical distance between ship's bottom and lowest side longitudinal, in mm (in).

Notes:-

1 The values of a and b are not to be taken as less than r.

2 *l* is to be measured in a straight line between the intersections of the longitudinals and the plating.

Side Shell

4305 Within 0,4L amidships the thickness of side shell plating is not to be less than required by the following formulæ:—

(a) with longitudinal framing

$$t = 0,0059 \, \text{s} \sqrt{\text{d}} \, \, \text{mm} \qquad \left(\, t = \frac{\text{s}}{308} \, \sqrt{\text{d}} \, \, \text{in} \right)$$

or
$$t = \frac{s}{1000} \left[10.6 + \frac{L_1}{30.5} \right] \text{ mm}$$

$$\left(t = \frac{s}{1000} \left[10.6 + \frac{L_1}{100} \right] \text{ in} \right)$$

whichever is the greater.

(b) with transverse framing

$$t = \frac{s + 150}{640} \sqrt{\frac{\text{d L}}{\text{D}}} \text{ mm } \left(t = \frac{s + 6}{1160} \sqrt{\frac{\text{d L}}{\text{D}}} \text{ in} \right)$$

In no case is the value of S used in the transverse framing formula to be less than:—

$$559 + 1{,}11$$
L mm $\left(22 + \frac{L}{75} \text{ in }\right)$ or 865 mm (34 in) whichever is the lesser.

The thickness of side shell need not exceed that determined from 4302 using the spacing of side shell frames or longitudinals.

4306 The midship thickness of side shell is to be gradually tapered to the end thickness. See 4308.

4307 Where the shear force has to be investigated (see D 4103) the thickness of the side shell plating is to be as required by 4305, or the following, whichever is the greater:—

$$t = \frac{F\left(0.16 + 0.075 \frac{A_s}{A_L}\right)_{mm}}{D q}$$

$$\left(t = \frac{F\left(0.16 + 0.075 \frac{A_s}{A_L}\right)_{in}}{12 D q}\right)$$

where F = shear force in still water, in tonnes (tons), taking into account, where applicable, local forces at transverse bulkheads,

A_S = area of side shell, in cm² (in²), at the section considered, taken as plating area over a depth equal to D,

A_L = area of longitudinal bulkhead, in cm² (in²), at the section considered, taken as the sum of the plating areas from bottom to deck,

q = shear stress, in kg/mm² (ton/in²), as given in Table D 43.1.

Note. The values of A_S and A_L are to be determined using the original thicknesses of side shell and longitudinal bulkhead.

TABLE D 43.1

STATION	SHEAR STRESS	STATION	SHEAR STRESS
The la	kg/mm²	ne mail 6	kg/mm²
	(ton/in ²)		(ton/in2)
AP	8,25 (5 · 23)	51	7,65 (4.84)
1	7.81 (4.95)	6	7.21 (4.57)
î	7,37 (4.68)	61	6,77 (4 · 29)
11	6,93 (4.40)	7	6,49 (4.13)
2	6,66 (4.24)	71	6,49 (4.13)
	6,49 (4.13)	8	6,66 (4.24)
$\frac{2\frac{1}{2}}{3}$	6,60 (4.18)	81	7.04 (4.46)
	6,82 (4.35)	8½ 9	7,54 (4.79)
$\frac{3\frac{1}{2}}{4}$	7,26 (4.62)	91	7,98 (5.06)
41	7,81 (4.95)	FP	8,25 (5.23)
5	8,25 (5.23)	_	- (0 20)

End Thickness

4308 The thickness of shell plating for 0,05L at the fore end and 0,1L at the aft end is not to be less than:—

$$\left(6.5 + \frac{L}{30}\right)\sqrt{\frac{s}{s_b}}\,\mathrm{mm} \quad \left(\left(0.255 + \frac{L}{2500}\right)\sqrt{\frac{s}{s_b}}\,\mathrm{in}\,\right)$$

where $s_b = \text{standard frame spacing, in mm (in), as}$ given in D 705 and D 706.

Sheerstrake

4309 The width of sheerstrake for 0,5 L amidships is not to be less than 150D mm (0·15D ft) but need not exceed 2135 mm (84 in) and the thickness is not to be less than that of the deck plating or side shell, whichever is the greater.

At ends the thickness of sheerstrake may be the same as the side shell.

4310 The thickness of the sheerstrake is to be increased 20 per cent at the ends of the bridge, but this increase is not required if the bridge does not extend to the ship's side

If the poop front at side extends within 0,25L from amidships the sheerstrake at the break is to be increased by 20 per cent. No increase is required if the poop front at side is 0,3L from amidships or greater. The increase at intermediate positions is to be obtained by interpolation and is to be applied to the tapered thickness of the sheerstrake.

4311 The upper edge of the sheerstrake is to be dressed smooth and kept free of isolated welded fittings or connections. In ships over 150 m (492 ft) in length scupper openings are not to be cut above the deck within 0,5L amidships or in way of breaks of superstructures.

Where a rounded sheerstrake is adopted, the welding of fairleads or other fittings to this plate is to be reduced to a minimum and details are to be submitted for approval.

Openings in Shell

4312 Sea inlets in pump rooms situated within 0,5L amidships, are, if practicable, to be fitted clear of the bilge radius. All openings are to be arranged so as to minimize discontinuity of transverse frames, longitudinals or bilge keels. Compensation is to be provided for all openings within 0,5L amidships and may be required for openings in the vicinity of the poop front. The compensation should, if possible, take the form of an insert plate rather than a doubler.

If openings are not circular or oval the corners are to be rounded with as large a radius as practicable.

Bilge Keels

4313 Where bilge keels are fitted, it is desirable that they be attached to a continuous flat bar which may be welded to the shell. Scallops are to be arranged in way of welded butts in the flat bar. Alternative arrangements, or arrangements omitting the flat bar, will be specially considered.

Bilge keels are to be gradually tapered at their ends and are not to finish on an unstiffened panel.

Section 44

BOTTOM, SIDE AND DECK LONGITUDINALS

Symbols

4401

L₁ = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft),

D = moulded depth, in metres (feet),

 D_1 = moulded depth, in metres (feet), but not to be taken as greater than 20 m (65·6 ft),

S = span, in metres (feet), measured between transverses or from transverse to "span point" (minimum value 2,5 m (8·2 ft)),

S = spacing of longitudinals, in mm (in),

h = distance of longitudinal below deck at side, in metres (feet).

Scantlings

4402 The scantlings of longitudinals within the range of cargo tanks are not to be less than required by the following formulæ:—

Bottom longitudinals
$$\frac{I}{y} = \frac{\text{s S}^2 D}{74} \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{\text{s S}^2 D}{1680} \text{ in}^3\right)$$

$$\begin{split} \text{Deck longitudinals} \quad & \frac{I}{y} = \frac{\text{s S}^2}{100} \left\{ 1,85 + \left(\frac{L_1}{109,7} \right)^3 \right\} \text{ cm}^3 \\ & \left(\frac{I}{y} = \frac{\text{s S}^2}{1200} \left\{ 3 \cdot 2 + \left(\frac{L_1}{300} \right)^3 \right\} \text{ in}^3 \right) \\ \text{Side longitudinals} \quad & \frac{I}{y} = \frac{\text{s S}^2}{118} \left(h + \frac{D_1}{6} \right) \text{cm}^3 \\ & \left(\frac{I}{y} = \frac{\text{s S}^2}{2680} \left(h + \frac{D_1}{6} \right) \text{in}^3 \right) \end{split}$$

The section modulus given by these formulæ is that of the longitudinal and associated plating. (See D 5302.)

The scantlings derived from the above, using the midship thickness of plating, are to extend throughout the cargo tanks.

4403 The scantlings of bilge longitudinals are to be graduated between those required for the bottom and lowest side longitudinals.

4404 Where flat bars are used for longitudinals and these are continuous at bulkheads, the thickness is not to be less than one-eighteenth of the depth; otherwise, the thickness should not be less than one-fifteenth of the depth.

Where built sections are used the breadth of face bar is not to be less than given below:

(a) For longitudinals within 0,15D of base line and deck line

$$b_F = k_1 S mm$$

$$(b_{\rm F} = .012 \, {\rm k, \, S \, in}).$$

-assymmetrical face bars

$$b_F = k, k, S mm$$

$$(b_F = .012 \, k_1 \, k_3 \, S \, in).$$

The ratio of web depth to web thickness is not to exceed 55:1, i.e. $\frac{t_W}{d}$ is not to be less than 0,0182 (see also D 5309).

- (b) For longitudinals within 0,35D of mid-depth
 - -symmetrical face bars

$$b_F = k_a S mm$$

$$(b_F = .012 \text{ k, S in}).$$

-assymmetrical face bars

$$b_F = k_2 k_3 S mm$$

$$(b_F = .012 k_2 k_3 S in).$$

The ratio of web depth to web thickness is not to exceed 60:1, i.e. $\frac{t_W}{d}$ is not to be less than 0,0167 (see also D 5309).

where b_F = minimum breadth of face bar, in mm (in),

k₁, k₂ and k₃ are determined from Figs. D 44.1, D 44.2 and D 44.3,

 A_W = sectional area of web of longitudinal, in cm² (in²),

A_F = sectional area of face bar, in cm² (in²),

tw = thickness of web, in mm (in),

d = depth of web, in mm (in),

S = span of longitudinal, in metres (feet), but not to be taken less than 2,44 m (8 ft).

Note. Figs. D 44.1, D 44.2 and D 44.3 represent the following formulæ:—

$$\begin{aligned} \mathbf{k_1} &= 25 \sqrt{1 + \frac{\mathsf{A_W}}{2 \, \mathsf{A_F}}} \left[1 - \left(\frac{20 \, \mathsf{t_W}}{\mathsf{d}} \right)^2 \right] \\ \mathbf{k_2} &= 20 \sqrt{1 + \frac{\mathsf{A_W}}{1,66 \, \mathsf{A_F}}} \left[1 - \left(\frac{25 \, \mathsf{t_W}}{\mathsf{d}} \right)^2 \right] \\ \mathbf{k_3} &= \frac{1}{\sqrt{1 + 0.35 \sqrt{\frac{\mathsf{A_W}}{\mathsf{A_F}}}}} \end{aligned}$$

Higher Tensile Steel

4405 For additional requirements when higher tensile steel is used, see D 6513.

Connections

4406 End connections of longitudinals to bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of longitudinal strength.

4407 Where the length exceeds 215 m (705 ft) it is desirable that the bottom and deck longitudinals be continuous through the transverse bulkheads but alternative arrangements will be specially considered.

4408 Longitudinals are to be connected to the transverses as required by Table D 57.6. In ships above 200 m (656 ft) all longitudinals (including those on longitudinal bulkheads) are to have the web attached to the transverses. In ships between 155 and 200 m (508 and 656 ft), similar arrangements are to be made except that side longitudinals and longitudinal bulkhead horizontal stiffeners need not have the webs attached unless they are within 3 m (9.84 ft) of the bottom or deck.

Section 45

TRANSVERSE SIDE FRAMING

Symbols

4501

D = moulded depth, in metres (feet), to deck at side amidships,

S = span, in metres (feet), measured between stringers or from stringer to "span point",

S = frame spacing, in mm (in),

h = head, in metres (feet), from mid-point of span to deck at side measured at mid-length of tank.

Scantlings

4502 Where, in tankers not exceeding 200 m (656 ft) in length, transverse side framing is adopted in the cargo tanks, the section modulus of side frames is not to be less than:—

$$\frac{I}{V} = \frac{s h S^2}{97.5} \text{ cm}^3$$
 $\left(\frac{I}{V} = \frac{s h S^2}{2220} \text{ in}^3\right)$

where side transverses are fitted,

or
$$\frac{I}{y} = \frac{s h S^2}{83.3} cm^3 \left(\frac{I}{y} = \frac{s h S^2}{1890} in^3 \right)$$

where side transverses are not fitted.

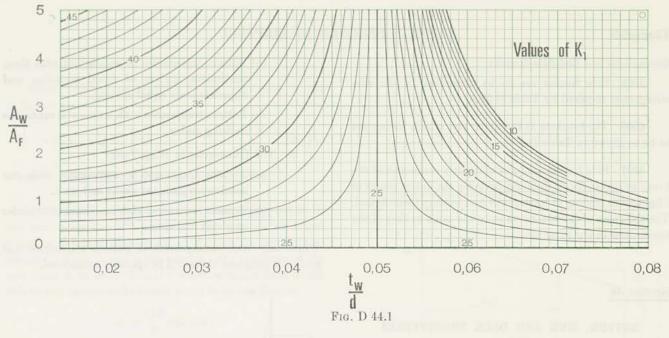
The size of the frame is to be governed by the maximum modulus derived from the above formula and is to be maintained for the full depth of the ship. The modulus given is that of the frame and associated side shell plating. See D 5302.

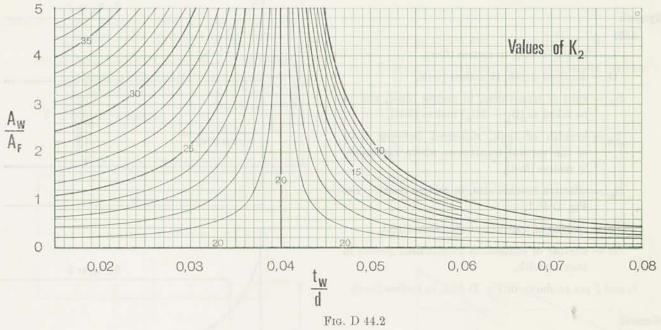
Side Stringers

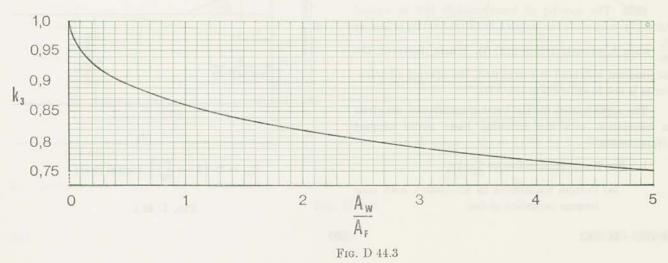
4503 Where the depth D does not exceed 7,5 m (25 ft), one side stringer is to be fitted. Where D exceeds 7,5 m (25 ft) but does not exceed 11 m (36 ft), 2 stringers are required and over 11 m (36 ft) depth, 3 stringers. For scantlings of stringers, see D 4703.

Side Transverses

4504 Where the depth D exceeds 11 m (36 ft), or the distance between transverse bulkheads (whether oiltight or non-oiltight) exceeds 15 m (49 ft), side transverses are to be fitted in line with the bottom transverses. The scantlings of the side transverses are to be determined in accordance with D 4607.







Connections and End Attachments

4505 Side frames are to be connected to the side stringers as required by Table D 57.6.

4506 The brackets at the upper end of side frames are to be as shown in Table D 57.5.

4507 Side frames are to be efficiently connected at the lower end to stiffened brackets covering the entire round of bilge and extending at least to the first bottom longitudinal. The thickness of the bracket is to be the same as that of the transverses in the wing tank.

Section 46

BOTTOM, SIDE AND DECK TRANSVERSES

Symbols

4601

L = length of ship, in metres (feet),

D = moulded depth, in metres (feet),

 $S_T = \text{span of transverses, in metres (feet), and to}$ be taken as $(b_t - 2b_e)$ metres (feet),

b_t = breadth of tank, measured between faces of the vertical transverses where applicable, in metres (feet),

 $b_e = \text{effective bracket size, in metres (feet)}.$ See Fig. D 46.1,

S = spacing of transverses, in metres (feet),

n = number of continuous longitudinal girders in tank breadth,

h and I are as shown in Fig. D 46.3, in metres (feet).

General

4602 The spacing of transverses is not to exceed 3,6 m (11.8 ft) when the length L is 180 m (590 ft) or less, or L when L exceeds 180 m (590 ft). Where, however, the longitudinal bulkhead is corrugated, the spacing of transverses is not to exceed 5 m (16.5 ft).

The requirements for the bottom transverses are given in association with the following basic girder support arrangements:—

1. For Transverses in Centre Tanks

(a) Bottom transverses in association with continuous centreline girder.

- (b) Bottom transverses in association with three continuous girders of equal scantling and approximately equal spacing.
- (c) Bottom transverses with intercostal centreline docking girder.

2. For Transverses in Wing Tanks

- (a) Bottom transverse in association with one continuous girder at about mid-span.
- (b) Bottom transverse with one intercostal girder at about mid-span.

Where any other arrangement of bottom transverses and girders is proposed these will be specially considered.

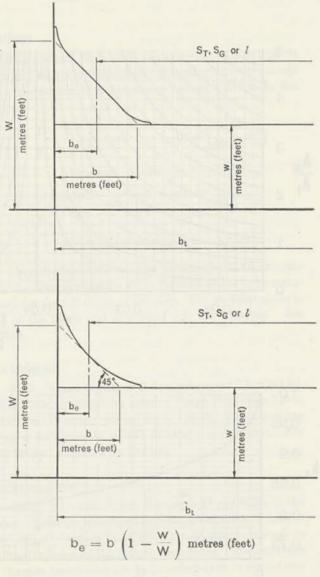


Fig. D 46.1

Bottom Transverses

4603 The section modulus of the transverses is not to be less than:—

$$\frac{\rm I}{\rm V} = 62 \; {\rm K_1 \, s \, D \, \, S_T^2 \, \, cm^3} \qquad \left(\frac{\rm I}{\rm y} = \frac{{\rm K_1 \, s \, D \, \, S_T^2}}{30 \cdot 63} \; {\rm in^3}\right)$$

where K₁ is a coefficient obtained from Table D 46.1.

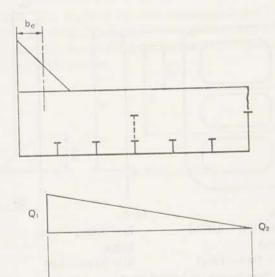
4604 The depth of the bottom transverse is not to be less than either one fifth of its span, between girders where fitted, or 2,5 times the depth of the slot for the bottom longitudinal whichever is the greater. The thickness of the web plate is to be such that the net sectional area of the web at any section of its length is not to be less than:—

$$A = \frac{Qx}{F} em^2 (in^2)$$

where A = net sectional area of the web, including bracket where applicable, in cm² (in²),

 Q_X = shear force at the actual section under consideration obtained from diagrams constructed in accordance with a, b or c of Fig. D 46.2,

F = 0,85 (5.4 British).

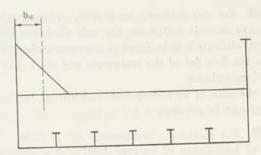


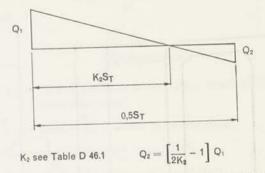
$$K_2 = 0,5$$
 $Q_2 = 0$

(a) BOTTOM TRANSVERSES WITH INTERCOSTAL GIRDERS

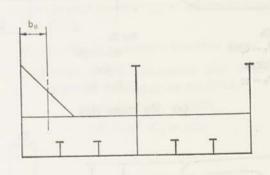
0,557

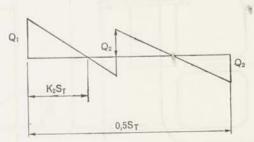
Fig. D 46.2





(b) BOTTOM TRANSVERSES WITH CONTINUOUS GIRDER





K₂ see Table D 46.1 Q₂ = 0,5Q₁

(c) BOTTOM TRANSVERSE WITH THREE CONTINUOUS GIRDERS

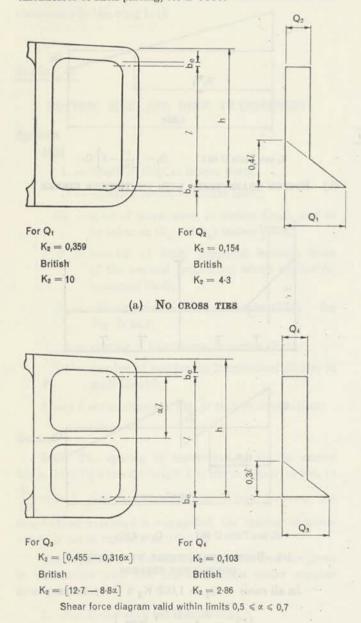
In all cases $~{\rm Q_1=1,025~K_2~S~D~S_T}$ tonnes

$$\left(\mathsf{Q}_1 = \frac{\mathsf{K_2} \, \mathsf{S} \, \mathsf{D} \, \mathsf{S}_\mathsf{T}}{35} \, \mathsf{tons} \, \right)$$

4605 For web stiffening, see D 5708. Where the depth of the web exceeds 200 times the web thickness then a horizontal stiffener is to be fitted at approximately midway between the face flat of the transverse and the top of the bottom longitudinals.

In the case of very deep webs, additional horizontal stiffening may be required.

4606 For minimum thicknesses, see D 5309. For moduli of transverses of various depths, face areas and thicknesses of shell plating, see D 5306.



(b) ONE CROSS TIE

Side Transverses

4607 The section modulus of the transverse is not to be less than:—

$$\frac{\mathrm{I}}{\mathrm{y}} = \mathrm{K}_{1} \, \mathrm{s} \, \mathrm{h} \, l^{2} \, \mathrm{cm}^{3} \qquad \left(\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{K}_{1} \, \mathrm{s} \, \mathrm{h} \, l^{2}}{10\,000} \, \mathrm{in}^{3} \right)$$

where K₁ = 3,72 (19·6 British) where no cross tie fitted, 2,16 (11·4 British) where one cross tie fitted, 1,88 (9·9 British) where two or more cross ties fitted.

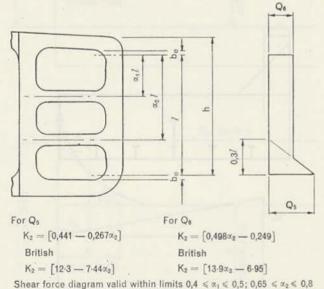
4608 The depth of the side transverse web is not to be less than 2,5 times the depth of the slot for the adjacent side longitudinals and the thickness of the web is to be such that the net sectional area of the web at any section is not to be less than:—

$$A = \frac{Qx}{F} cm^2 (in^2)$$

where A = net sectional area of the web, including bracket where applicable, in cm² (in²),

 Q_X = shear force at the actual section under consideration obtained from diagrams constructed in accordance with a, b or c of Fig. D 46.3,

F = 0.85 (5.4 British).



(c) Two cross ties

In all cases Q = K2 h S / tonnes

$$\left(Q = \frac{K_2 h s l}{1000} tons\right)$$

Fig. D 46.3

4609 For web stiffening, see D 5708. Where the depth of the web exceeds 100 times the web thickness then a vertical stiffener is to be fitted at approximately mid-depth.

4610 If side transverses are tapered, the increase in depth at the bottom, and decrease at the top, is not to exceed 10 per cent of the mean depth.

4611 For minimum thicknesses, see D 5309. For moduli of transverses of various depths, face areas and thicknesses of shell plating, see D 5306.

Deck Transverses

4612 The section modulus of the transverses is not to be less than:—

$$\begin{split} \frac{I}{y} &= 53,75 \; (0,0269 \; \text{s L} + 0,8) \; (\text{S}_1 + 1,83) \; \text{cm}^3 \\ \left(\frac{I}{y} &= (0 \cdot 0025 \; \text{s L} + 0 \cdot 8) \; (\text{S}_1 + 6) \; \text{in}^3\right) \\ \text{S}_1 &= \frac{\text{S}_T}{(n+1)} \; \text{metres (feet)} \; \; \text{but not less than} \; \frac{\text{b}_t}{6}. \end{split}$$

4613 If intercostal side girders are fitted, and their scantlings are in accordance with D 4811, the modulus of the deck transverses derived in accordance with the above formula may be reduced by 5 per cent.

4614 The depth of the deck transverse is not to be less than one sixth of its span, between girders where fitted, or 2,5 times the depth of the slot for the deck longitudinal, whichever is the greater.

4615 For minimum thicknesses, see D 5309. For moduli of transverses of various depths, face areas and thicknesses of deck plating, see D 5306.

TABLE D 46.1-VALUES OF COEFFICIENTS K, AND K2

General

$$\alpha = \frac{l_T - S_G}{2s}$$

$$\beta = \frac{S_G^3}{S_T^3} \, \frac{I_T}{I_G}$$

where S_G = span of girder, in metres (feet), (see D 4803 for minimum value),

S_T = span of transverses, in metres (feet),

 $I_G = \text{inertia of girder, in cm}^4 \text{ (in}^4),$

I_T = inertia of transverses, in cm⁴ (in⁴),

 $l_{\mathsf{T}} = \text{distance between support bulkheads, in metres}$ (feet),

S = spacing of transverses, in metres (feet).

(a) where bottom transverses with intercostal centreline docking girder are fitted:—

B.M. Coeff.
$$K_1 = 0.083$$

S.F. Coeff.
$$K_2 = 0,50$$

TABLE D 46.1

(b) 1 GIRDER 2 TRANSVERSES

			B.M. CO	EFF. K ₁			Bour of the		S.F. CO	EFF. K ₂		
β		AT SUL		x				au.	0	x		
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,210	0,210	0,195	0,175	0,125	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,04	0,210	0,210	0,195	0,175	0,125	0,0	0,960	0,960	0,980	1,000	1,000	1,000
0,06	0,210	0,210	0,195	0,170	0,125	0,0	0,940	0,940	0,960	0,980	1,000	1,000
0,08	0,205	0,205	0,190	0,167	0,125	0,0	0,920	0,920	0,940	0,970	1,000	1,000
0,10	0,200	0,200	0,185	0,165	0,125	0,0	0,900	0,900	0,920	0,960	0,990	1,000
0,20	0,180	0,180	0,170	0,150	0,120	0,0	0,800	0,820	0,860	0,920	0,980	1,000
0,40	0,150	0,150	0,150	0,135	0,115	0,0	0,670	0,730	0,760	0,840	0,950	1,000
0,60	0,130	0,130	0,135	0,125	0,110	0,0	0,580	0,630	0,690	0,790	0,910	1,000
0,80	0,120	0,120	0,120	0,120	0,105	0,0	0,520	0,540	0,630	0,730	0,880	1,000
1,00	0,100	0,100	0,115	0,115	0,100	0,0	0,460	0,500	0,580	0,680	0,850	1,000

					TRA	NSVERS	ES					
		The Park	в.м. со	EFF. K ₁	72	BIER			S.F. COE	FF. K ₂		10 1110
β			0	χ						α		
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,022	0,022	0,022	0,022	0,021	0,020	0,255	0,255	0,255	0,255	0,250	0,250
0,04	0,023	0,023	0,023	0,022	0,021	0,020	0,263	0,263	0,257	0,255	0,250	0,250
0,06	0,025	0,025	0,023	0,022	0,021	0,020	0,265	0,265	0,263	0,260	0,250	0,250
0,08	0,026	0,026	0,024	0,023	0,021	0,020	0,270	0,270	0,267	0,260	0,253	0,250
0,10	0,027	0,027	0,025	0,023	0,022	0,020	0,275	0,275	0,270	0,263	0,255	0,250
0,20	0,033	0,033	0,029	0,026	0,023	0,020	0,300	0,300	0,285	0,272	0,257	0,250
0,40	0,041	0,041	0,036	0,032	0,025	0,020	0,330	0,330	0,307	0,287	0,265	0,250
0,60	0,047	0,047	0,041	0,036	0,026	0,020	0,355	0,355	0,325	0,302	0,273	0,25
0,80	0,051	0,051	0,045	0,038	0,028	0,020	0,370	0,370	0,342	0,315	0,278	0,25
1,00	0,054	0,054	0,048	0,041	0,030	0,020	0,385	0,385	0,355	0,327	0,285	0,250

TABLE D 46.1—continued

(b) 1 GIRDER 3 TRANSVERSES

					(HRDER						
		H drawn	B.M. C	OEFF. K ₁				A ATTITUDE	S.F. CO	EFF. K ₂		
β			(χ					(χ		8
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,290	0,290	0,290	0,270	0,200	0,120	1,400	1,400	1,500	1,500	1,500	1,500
0,04	0,290	0,290	0,290	0,270	0,200	0,120	1,400	1,400	1,500	1,500	1,500	1,500
0,06	0,290	0,290	0,290	0,260	0,200	0,120	1,380	1,400	1,500	1,500	1,500	1,500
0,08	0,280	0,280	0,280	0,250	0,195	0,115	1,340	1,370	1,470	1,470	1,480	1,500
0,10	0,275	0,275	0,275	0,240	0,190	0,115	1,320	1,340	1,420	1,440	1,460	1,480
0,20	0,245	0,245	0,245	0,220	0,175	0,105	1,180	1,210	1,280	1,330	1,380	1,450
0,40	0,200	0,200	0,200	0,185	0,160	0,090	0,970	1,030	1,080	1,200	1,280	1,420
0,60	0,170	0,170	0,170	0,170	0,145	0,080	0,840	0,900	0,960	1,110	1,210	1,380
0,80	0,150	0,150	0,150	0,150	0,135	0,075	0,740	0,800	0,870	1,040	1,150	1,330
1,00	0,135	0,135	0,135	0,135	0,125	0,070	0,680	0,740	0,810	0,960	1,100	1,300

					TRA	NSVERS	SES					
			B.M. CO	EFF. K ₁					S.F. CO	EFF. K ₂		
β			(χ				-	0			0
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,025	0,025	0,024	0,023	0,022	0,022	0,258	0,258	0,257	0,252	0,252	0,252
0,04	0,026	0,026	0,025	0,024	0,023	0,023	0,267	0,267	0,267	0,262	0,262	0,260
0,06	0,028	0,028	0,026	0,026	0,025	0,024	0,275	0,275	0,275	0,270	0,270	0,265
0,08	0,030	0,030	0,028	0,028	0,026	0,026	0,285	0,285	0,280	0,272	0,272	0,275
0,10	0,032	0,032	0,029	0,029	0,028	0,027	0,292	0,292	0,287	0,277	0,275	0,27
0,20	0,040	0,040	0,037	0,035	0,033	0,032	0,325	0,325	0,315	0,310	0,300	0,28
0,40	0,052	0,052	0,049	0,046	0,041	0,039	0,372	0,372	0,360	0,345	0,332	0,320
0,60	0,059	0,059	0,057	0,054	0,048	0,045	0,405	0,405	0,392	0,375	0,357	0,345
0,80	0,065	0,065	0,063	0,059	0,053	0,049	0,425	0,425	0,415	0,390	0,377	0,360
1,00	0,069	0,069	0,066	0,063	0,056	0,052	0,440	0,440	0,432	0,415	0,395	0,37

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TABLE D 46.1—continued

(b) 1 GIRDER 4 TRANSVERSES

					0	HRDER						
		d , maco	B.M. CO	EFF. K ₁			1	- timuo	S.F. CO	EFF. K ₂		
β		36	(χ	(g)				(x		A
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,370	0,350	0,330	0,315	0,275	0,215	1,890	1,890	1,920	1,940	1,960	1,990
0,04	0,370	0,350	0,330	0,315	0,275	0,215	1,870	1,870	1,900	1,930	1,940	1,960
0,06	0,360	0,350	0,330	0,310	0,270	0,205	1,820	1,820	1,870	1,890	1,920	1,940
0,08	0,350	0,340	0,320	0,300	0,260	0,200	1,760	1,800	1,820	1,840	1,880	1,920
0,10	0,340	0,330	0,315	0,290	0,255	0,195	1,700	1,750	1,790	1,830	1,860	1,900
0,20	0,300	0,300	0,275	0,260	0,230	0,180	1,500	1,580	1,630	1,700	1,780	1,820
0,40	0,240	0,240	0,230	0,220	0,200	0,155	1,240	1,300	1,400	1,540	1,620	1,700
0,60	0,200	0,200	0,200	0,200	0,175	0,135	1,060	1,120	1,250	1,400	1,500	1,600
0,80	0,175	0,175	0,175	0,175	0,165	0,120	0,940	1,000	1,150	1,270	1,420	1,520
1,00	0,150	0,150	0,150	0,150	0,150	0,105	0,850	0,920	1,050	1,200	1,340	1,460

					TRA	NSVERS	ES					
		d .miron	в.м. со	DEFF. K ₁					S.F. CO	EFF. K ₂		
β			0	K.						α		4
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,025	0,025	0,024	0,024	0,023	0,023	0,255	0,255	0,255	0,255	0,253	0,250
0,04	0,027	0,026	0,026	0,025	0,025	0,024	0,272	0,270	0,268	0,266	0,260	0,25
0,06	0,029	0,029	0,028	0,027	0,026	0,025	0,282	0,280	0,275	0,272	0,270	0,263
0,08	0,031	0,031	0,030	0,028	0,028	0,027	0,292	0,287	0,285	0,280	0,275	0,270
0,10	0,033	0,033	0,032	0,030	0,029	0,028	0,300	0,295	0,290	0,285	0,280	0,278
0,20	0,042	0,041	0,039	0,037	0,035	-0,033	0,335	0,325	0,320	0,313	0,307	0,300
0,40	0,053	0,051	0,050	0,047	0,044	0,041	0,380	0,372	0,362	0,352	0,342	0,330
0,60	0,061	0,059	0,057	0,054	0,050	0,047	0,412	0,405	0,387	0,376	0,365	0,355
0,80	0,066	0,065	0,062	0,058	0,054	0,051	0,435	0,425	0,412	0,400	0,382	0,370
1,00	0,070	0,068	0,065	0,062	0,058	0,055	0,450	0,437	0,427	0,412	0,395	0,388

TABLE D 46.1—continued

(b) 1 GIRDER 5 TRANSVERSES

						GIR	RDER					
	0	i amo	B.M. Co	OEFF. K ₁				II south	S.F. CO	EFF. K ₂		
β			(χ						α		
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,455	0,440	0,410	0,380	0,345	0,300	2,330	2,350	2,370	2,400	2,420	2,450
0,04	0,445	0,430	0,410	0,380	0,345	0,300	2,310	2,340	2,360	2,380	2,410	2,440
0,06	0,430	0,415	0,395	0,370	0,340	0,295	2,250	2,290	2,300	2,340	2,380	2,400
0,08	0,415	0,400	0,385	0,365	0,330	0,290	2,180	2,230	2,280	2,290	2,340	2,360
0,10	0,400	0,390	0,375	0,355	0,320	0,280	2,110	2,170	2,200	2,240	2,300	2,320
0,20	0,345	0,340	0,330	0,315	0,285	0,250	1,840	1,920	2,000	2,040	2,130	2,180
0,40	0,270	0,265	0,265	0,265	0,235	0,200	1,500	1,600	1,700	1,790	1,900	1,970
0,60	0,220	0,220	0,220	0,220	0,200	0,165	1,280	1,380	1,500	1,610	1,650	1,840
0,80	0,185	0,185	0,185	0,185	0,175	0,140	1,140	1,230	1,370	1,500	1,620	1,740
1,00	0,165	0,165	0,165	0,165	0,160	0,125	1,040	1,140	1,280	1,420	1,540	1,650

						TRANSV	ERSES					
		A H	B.M. Co	DEFF. K ₁					S.F. CC	DEFF. K ₂		
β				α						α		
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,025	0,025	0,025	0,024	0,024	0,023	0,265	0,265	0,263	0,260	0,257	0,255
0,04	0,028	0,028	0,028	0,027	0,026	0,025	0,280	0,280	0,275	0,270	0,267	0,265
0,06	0,031	0,031	0,030	0,029	0,028	0,027	0,290	0,287	0,284	0,280	0,277	0,275
0,08	0,034	0,034	0,033	0,032	0,031	0,030	0,303	0,300	0,295	0,290	0,287	0,283
0,10	0,037	0,036	0,036	0,034	0,033	0,032	0,312	0,309	0,305	0,300	0,297	0,299
0,20	0,046	0,046	0,045	0,043	0,043	0,041	0,352	0,349	0,343	0,337	0,330	0,325
0,40	0,060	0,058	0,057	0,055	0,054	0,053	0,405	0,402	0,393	0,383	0,378	0,375
0,60	0,068	0,067	0,065	0,064	0,063	0,061	0,435	0,432	0,426	0,417	0,412	0,40
0,80	0,073	0,072	0,071	0,069	0,068	0,067	0,455	0,452	0,446	0,440	0,436	0,43
1,00	0,077	0,076	0,074	0,073	0,071	0,070	0,470	0,467	0,461	0,455	0,450	0,44

LLOYD'S REGISTER OF SHIPPING

TABLE D 46.1—continued

(c) 3 GIRDERS 2 TRANSVERSES

					G	IRDERS	\$					
		N Avenue	в.м. со	EFF. K ₁	1		- 0	, cure	S.F. C	DEFF. K ₂		
β		- 4	(x				23		α		ą
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,04	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,06	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,08	0,240	0,230	C,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,10	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,20	0,235	0,227	0,219	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,40	0,215	0,215	0,200	0,189	0,135	0,0	0,960	0,980	1,000	1,000	1,000	1,000
0,60	0,195	0,195	0,195	0,180	0,135	0,0	0,870	0,900	0,950	1,000	1,000	1,000
0,80	0,175	0,175	0,175	0,170	0,135	0,0	0,790	0,840	0,890	1,000	1,000	1,000
1,00	0,165	0,165	0,165	0,160	0,125	0,0	0,720	0,770	0,840	0,960	1,000	1,000

					TRA	NSVERS	ES					
		M armon	B.M. CO	EFF. K ₁				Y .TCDIII	S.F. CO	EFF. K ₂		
β			i i	α					10	α		1
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,007	0,006	0,006	0,005	0,005	0,005	0,147	0,145	0,140	0,137	0,137	0,12
0,04	0,009	0,007	0,007	0,006	0,005	0,005	0,147	0,145	0,140	0,137	0,137	0,12
0,06	0,010	0,008	0,008	0,007	0,006	0,005	0,155	0,152	0,142	0,137	0,137	0,12
0,08	0,011	0,009	0,009	0,008	0,007	0,005	0,163	0,157	0,150	0,140	0,137	0,12
0,10	0,013	0,011	0,011	0,009	0,007	0,005	0,167	0,165	0,155	0,145	0,137	0,12
0,20	0,018	0,015	0,015	0,012	0,008	0,005	0,195	0,186	0,180	0,162	0,144	0,12
0,40	0,026	0,023	0,021	0,017	0,010	0,005	0,235	0,220	0,210	0,185	0,152	0,12
0,60	0,032	0,029	0,025	0,020	0,011	0,005	0,262	0,247	0,232	0,202	0,160	0,12
0,80	0,037	0,033	0,029	0,022	0,013	0,005	0,285	0,270	0,250	0,217	0,165	0,12
1,00	0,041	0,038	0,033	0,025	0,014	0,005	0,302	0,287	0,267	0,230	0,170	0,12

TABLE D 46.1—continued

(c) 3 GIRDERS 3 TRANSVERSES

					G	IRDERS							
		H arm	B.M. CO	EFF. K ₁			s.f. coeff. K ₂						
β			(χ			α						
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0	
0,02	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620	
0,04	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620	
0,06	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620	
0,08	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620	
0,10	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620	
0,20	0,325	0,310	0,290	0,260	0,210	0,140	1,540	1,620	1,620	1,620	1,620	1,620	
0,40	0,285	0,275	0,265	0,240	0,200	0,125	1,370	1,420	1,460	1,500	1,500	1,500	
0,60	0,255	0,250	0,245	0,225	0,185	0,115	1,240	1,300	1,360	1,440	1,450	1,450	
0,80	0,225	0,225	0,220	0,210	0,180	0,105	1,120	1,200	1,280	1,360	1,420	1,420	
1,00	0,205	0,205	0,205	0,200	0,170	0,095	1,040	1,120	1,200	1,300	1,400	1,400	

					TRA	NSVERS	ES					
		4 -	B.M. CO	EFF. K ₁				7 1	S.F. (COEFF. K	2	
β			o	c						α		
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,009	0,008	0,007	0,006	0,005	0,004	0,150	0,145	0,140	0,135	0,130	0,125
0,04	0,011	0,010	0,009	0,008	0,007	0,006	0,162	0,157	0,153	0,148	0,143	0,138
0,06	0,013	0,012	0,011	0,010	0,009	0,008	0,175	0,170	0,163	0,158	0,150	0,147
0,08	0,015	0,014	0,013	0,012	0,011	0,010	0,185	0,180	0,170	0,165	0,157	0,155
0,10	0,017	0,016	0,015	0,014	0,013	0,011	0,192	0,187	0,180	0,175	0,165	0,160
0,20	0,025	0,024	0,023	0,021	0,018	0,017	0,230	0,225	0,220	0,210	0,195	0,185
0,40	0,036	0,035	0,034	0,031	0,027	0,024	0,285	0,275	0,270	0,257	0,237	0,220
0,60	0,045	0,044	0,043	0,038	0,033	0,029	0,325	0,315	0,305	0,290	0,267	0,247
0,80	0,051	0,050	0,048	0,043	0,038	0,033	0,355	0,345	0,330	0,317	0,290	0,270
1,00	0,056	0,055	0,052	0,047	0,043	0,036	0,380	0,370	0,355	0,340	0,310	0,287

LLOYD'S REGISTER OF SHIPPING

TABLE D 46.1—continued

(c) 3 GIRDERS 4 TRANSVERSES

					G	IRDERS							
	Ks	June .	B.M. CO	EFF. K ₁		\	S.F. COEFF. K2						
β				χ				100		α		2	
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0	
0,02	0,435	0,435	0,390	0,355	0,315	0,250	2,160	2,160	2,160	2,160	2,160	2,160	
0,04	0,435	0,435	0,390	0,355	0,315	0,250	2,160	2,160	2,160	2,160	2,160	2,160	
0,06	0,435	0,435	0,390	0,355	0,315	0,250	2,160	2,160	2,160	2,160	2,160	2,160	
0,08	0,435	0,435	0,390	0,355	0,315	0,250	2,150	2,160	2,160	2,160	2,160	2,160	
0,10	0,433	0,433	0,385	0,355	0,305	0,245	2,130	2,150	2,150	2,160	2,160	2,160	
0,20	0,395	0,395	0,365	0,335	0,295	0,235	1,980	2,040	2,050	2,060	2,080	2,100	
0,40	0,340	0,340	0,325	0,300	0,265	0,210	1,740	1,800	1,860	1,860	1,920	1,970	
0,60	0,300	0,300	0,290	0,275	0,245	0,190	1,580	1,630	1,710	1,760	1,840	1,870	
0,80	0,265	0,265	0,265	0,255	0,225	0,175	1,400	1,470	1,580	1,680	1,760	1,800	
1,00	0,240	0,240	0,240	0,240	0,210	0,160	1,280	1,360	1,480	1,620	1,700	1,740	

					TRANS	SVERSES	3					
	1	Amon	B.M. CO	EFF. K ₁				N . venu	S.F. CO	EFF. K ₂		
β				α						α		9
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,010	0,010	0,010	0,010	0,010	0,010	0,152	0,147	0,142	0,137	0,132	0,127
0,04	0,012	0,011	0,011	0,010	0,010	0,010	0,167	0,160	0,157	0,155	0,150	0,148
0,06	0,014	0,013	0,013	0,012	0,011	0,011	0,180	0,172	0,170	0,165	0,160	0,15
0,08	0,016	0,015	0,014	0,013	0,012	0,012	0,187	0,182	0,180	0,175	0,167	0,160
0,10	0,018	0,017	0,016	0,014	0,014	0,013	0,197	0,192	0,187	0,182	0,175	0,16
0,20	0,027	0,026	0,023	0,022	0,020	0,018	0,242	0,232	0,225	0,215	0,207	0,198
0,40	0,039	0,038	0,035	0,033	0,029	0,025	0,295	0,285	0,275	0,262	0,250	0,238
0,60	0,048	0,046	0,043	0,042	0,035	0,032	0,335	0,325	0,312	0,297	0,280	0,265
0,80	0,054	0,052	0,049	0,045	0,041	0,037	0,370	0,355	0,340	0,325	0,305	0,28
1,00	0,059	0,057	0,053	0,050	0,045	0,041	0,390	0,380	0,362	0,347	0,325	0,30

TABLE D 46.1—continued

(c) 3 GIRDERS 5 TRANSVERSES

					G	IRDERS							
			B.M. CO	EFF. K ₁			s.f. coeff. K ₂						
β				α						x			
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0	
0,02	0,530	0,510	0,475	0,440	0,400	0,345	2,700	2,700	2,700	2,700	2,700	2,700	
0,04	0,530	0,510	0,475	0,440	0,400	0,345	2,700	2,700	2,700	2,700	2,700	2,700	
0,06	0,525	0,510	0,475	0,440	0,400	0,345	2,680	2,680	2,680	2,680	2,680	2,680	
0,08	0,523	0,500	0,475	0,440	0,400	0,345	2,660	2,660	2,660	2,660	2,660	2,680	
0,10	0,513	0,495	0,470	0,435	0,395	0,340	2,630	2,630	2,640	2,640	2,650	2,660	
0,20	0,465	0,455	0,435	0,410	0,370	0,320	2,440	2,480	2,500	2,520	2,530	2,560	
0,40	0,400	0,390	0,380	0,360	0,325	0,280	2,120	2,180	2,240	2,300	2,340	2,370	
0,60	0,340	0,340	0,330	0,320	0,290	0,250	1,860	1,960	2,040	2,140	2,180	2,220	
0,80	0,305	0,305	0,300	0,290	0,270	0,230	1,660	1,780	1,880	2,000	2,050	2,100	
1,00	0,275	0,275	0,275	0,265	0,245	0,210	1,530	1,630	1,750	1,890	1,950	2,000	

					TRA	NSVERS	ES							
			в.м. со	EFF. K ₁			s.f. coeff. K ₂							
β			C	x			α							
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0		
0,02	0,005	0,005	0,004	0,004	0,003	0,003	0,150	0,150	0,148	0,146	0,144	0,142		
0,04	0,014	0,013	0,013	0,012	0,012	0,011	0,170	0,170	0,167	0,163	0,160	0,157		
0,06	0,016	0,015	0,015	0,014	0,014	0,013	0,187	0,187	0,184	0,180	0,177	0,173		
0,08	0,019	0,018	0,018	0,017	0,017	0,016	0,205	0,205	0,198	0,194	0,189	0,183		
0,10	0,021	0,020	0,020	0,019	0,019	0,018	0,215	0,215	0,207	0,202	0,198	0,193		
0,20	0,032	0,030	0,030	0,029	0,028	0,026	0,265	0,265	0,252	0,245	0,239	0,232		
0,40	0,045	0,044	0,042	0,041	0,038	0,037	0,325	0,325	0,310	0,300	0,290	0,280		
0,60	0,055	0,054	0,051	0,050	0,047	0,045	0,367	0,362	0,350	0,342	0,336	0,330		
0,80	0,062	0,060	0,059	0,057	0,054	0,051	0,400	0,400	0,375	0,365	0,355	0,345		
1,00	0,067	0,065	0,064	0,064	0,059	0,056	0,420	0,420	0,400	0,387	0,376	0,36		

Section 47

SIDE STRINGERS

Symbols

4701

- S = span from "span point" to "span point" or from "span point" to side transverse, in metres (feet), (minimum value to be taken as 3 m (9.84 ft)),
- b = width of plating supported, in metres (feet). Where applicable, the width supported is to be taken as half the distance from the next stringer to the deck at side or base line as appropriate,
- h = head from stringer to highest point of tank, excluding hatchway, in metres (feet).

General

4702 Where transverse side framing is adopted, side stringers are to be fitted as required by D 4503.

Scantlings

4703 The modulus of side stringers is not to be less than given by Table D 47.1:—

TABLE D 47.1

Position of Stringer	Section Modulus em ³	Section Modulus in ³
Single	13,55 b h S ²	b h S ² 140
Upper of two or more	17,25 b h S²	b h S ² 110
Middle or lower	13,55 b h S ²	b h S ²

4704 The depth of the stringer is not to be less than 2,5 times the depth of the slot for the frame.

4705 Where side transverses are not fitted the lower side stringers are to be supported by suitable buttress brackets from the bottom transverses.

4706 For minimum thicknesses, see D 5309.

For moduli of transverses of various depths, face areas and thicknesses of shell plating, see D 5306.

Section 48

BOTTOM AND DECK GIRDERS

Symbols

4801

L = length of ship, in metres (feet),

D = moulded depth, in metres (feet),

 $S_G = \text{span of girders, in metres (feet), see Fig.}$ D 48.1,

S = spacing of transverses, in metres (feet),

b_t = breadth of tank, measured between faces of the vertical transverses where applicable, in metres (feet),

n = number of continuous longitudinal girders in tank breadth,

m = number of transverses between support bulkheads.

General

4802 The scantling requirements for the bottom girders are given for three basic girder support arrangements (see D 4602). Where an arrangement of bottom transverses and girders other than those detailed is proposed this will be specially considered.

Bottom Girders

4803 The section modulus of the girder is not to be less than:—

$$\begin{split} \frac{I}{y} &= \frac{62 \; \text{K}_1 \; \text{b}_t \; \text{S}_G \; \text{D} \; \text{s}}{(n+1)} \; \text{cm}^3 \\ \left(\frac{I}{y} &= \frac{\text{K}_1 \; \text{b}_t \; \text{S}_G \; \text{D} \; \text{s}}{30 \cdot 63 \; (n+1)} \; \text{in}^3 \; \right) \end{split}$$

where $K_1 =$ coefficient derived from Table D 46.1. Minimum value of $S_G = s$ (m - 0.8) metres (feet).

For intercostal centreline docking girder, see 4805.

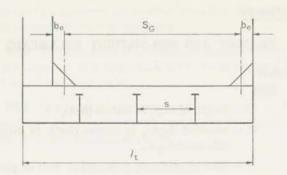
4804 The thickness of the girder web is to be such that the net sectional area of the web at any section in its length is not to be less than:—

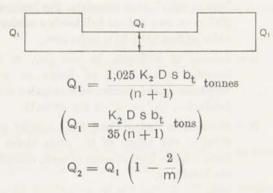
$$A = \frac{Qx}{F} cm^2 (in^2)$$

A = net sectional area of the web, including bracket where applicable, in cm² (in²),

Q_X = shear force at the actual section under consideration obtained from diagram constructed in accordance with Fig. D 48.1,

F = 0.85 (5.4 British).





where K₂ = coefficient derived from Table D 46.1,

be = effective bracket size, in metres (feet) (see Fig. D 46.1).

Intercostal Bottom Centreline Girder

4805 The section modulus of the girder is not to be less than:—

$$\frac{I}{y} = 3.6 b_t D s^2 cm^3$$
 $\left(\frac{I}{y} = \frac{b_t D s^2}{526} in^3\right)$

The scantlings of the docking girder may require to be increased depending upon docking condition and support arrangements, details of which are to be submitted.

4806 The depth of an intercostal girder is not to exceed the depth of the transverses.

Continuous or Intercostal Bottom Centreline Girders

4807 Vertical webs are generally to be arranged on the transverse bulkheads in association with bottom centreline girders.

4808 Flanged or otherwise stiffened brackets are to be fitted on both sides of the girder mid-way between the transverses with intermediate vertical stiffeners not more than 990 mm (39 in) apart. The brackets are to be connected to a suitable bottom longitudinal. In deep centreline girders horizontal stiffening is to be arranged and the brackets on one side may stop at a suitable horizontal stiffener. The intermediate vertical stiffeners may be omitted but where the spacing of brackets exceeds 1830 mm (72 in) an intermediate vertical stiffener is to be fitted to the lower part of the girder, or suitable horizontal stiffening is to be arranged.

Continuous Deck Girders

4809 A continuous deck centreline girder is to be fitted having a section modulus not less than:—

$$\frac{I}{y} = \frac{l^2 b L}{10,5} cm^3$$
 $\left(\frac{I}{y} = \frac{l^2 b L}{20000} in^3\right)$

where l = length of centre tank, in metres (feet),

b = half-breadth of centre tank, in metres (feet), or, where there is a vertical web on the inboard side of the longitudinal bulkheads, half the distance between the faces of the webs.

Where continuous side girders are fitted the section modulus of these and the centreline girder is to be derived from the above formula with

$$b = \frac{b_t}{(n+1)}$$

4810 Where intercostal side girders, having scantlings as required by 4811, are fitted in the centre tank the section modulus of the deck centre girder derived in accordance with 4809 may be reduced by 5 per cent.

Intercostal Deck Side Girders

4811 Intercostal side girders are to have a depth not less than 50 per cent of the depth of the deck transverse. The face area is not to be less than that of the transverses.

General

4812 For reduction to modulus of deck centre girder and deck transverses when side girders are fitted, see 4810 and D 4613.

4813 For minimum thicknesses, see D 5309.

For moduli of girders of various depths, face areas and thicknesses of shell or deck plating, see D 5306.

CROSS TIES

4901 Cross ties may be of plate or sectional material and are to have an area and least moment of inertia not less than:—

$$A = 64 + 1.035$$
 l h s cm²

$$A = 10 + \frac{l h s}{220} in^2$$
,

$$I = 2.45 l h s S^2 cm^4$$

$$\left(I = \frac{l h s S^2}{6500} in^4\right),$$

where l = one half the distance, in metres (feet), between the centre of the adjacent cross ties or between the centre of the adjacent cross tie and the centre of the bottom or deck transverse.

> h = vertical distance, in metres (feet), from the centre of the cross tie to deck at side amidships,

S = spacing of transverses, in metres (feet),

S = length of cross tie, in metres (feet), between the toes of the horizontal tripping brackets on the transverse webs at the cross ties. Special consideration will be given where alternative arrangements omitting the tripping brackets are provided.

Diagonal cross ties will be specially considered but, in general, the area and least moment of inertia of the horizontal cross tie is not to be less than 85 per cent of that required by the above formula assuming the centre cross tie only is fitted. The area of each diagonal cross tie is not to be less than 85 per cent of that required for the horizontal cross tie.

4902 Cross ties are to be connected to the vertical transverses or horizontal girders by suitable brackets. Tripping brackets are to be fitted to the transverses in way of the cross ties and where scallops for longitudinals or frames come in way of the cross ties they are to be closed by plate collars.

4903 Cross ties are to be provided with suitable horizontal stiffening to prevent buckling and twisting. Where the unsupported width of face plate exceeds 150 mm (6 in), additional vertical stiffening is to be arranged to support the face plate.

OILTIGHT AND NON-OILTIGHT BULKHEADS

Symbols

5001

L = length of ship, in metres (feet),

D = moulded depth, in metres (feet), to deck at side amidships,

S = span of stiffener, corrugation, web or girder, in metres (feet), measured between girders, girder to "span point" or "span point" to "span point", as appropriate. For horizontal girders on longitudinal bulkheads a minimum value of 3 m (9.84 ft) is to be used,

s = spacing of stiffeners, in mm (in), or the breadth, in mm (in), of flange or web, whichever is the greater, of corrugated bulkheads (i.e., "b" or "c" in Fig. D 50.1),

h = distance, in metres (feet), from a point onethird of the height of the plate above its lower edge to highest point of tank, excluding the hatchway,

h₁ = distance, in metres (feet), from centre of span to highest point of tank, excluding the hatchway,

b = width of plating supported, in metres (feet), or as stated otherwise.

OILTIGHT BULKHEADS

General

5002 Longitudinal bulkheads, other than at the centreline, are to be oiltight throughout the cargo tanks and may be plane or horizontally corrugated.

Longitudinal bulkheads may be perforated in pumprooms, cofferdams, stabilizer tanks and in other compart ments (where these are clear of the cargo tanks), provided suitable account is taken of the increased shear stresses.

When a wash bulkhead is fitted, the length or breadth of a tank may, for the purposes of 5016, be measured from the wash bulkhead to the oiltight bulkhead.

5003 Where the ship's side is framed longitudinally the stiffening on the longitudinal bulkheads is to be arranged horizontally. Vertical stiffening may be adopted in association with transverse side framing.

5004 Transverse bulkheads may be plane or with corrugations arranged horizontally or vertically. Where transverse bulkheads are vertically corrugated, adequate

resistance to transverse compressive forces is to be provided by horizontal stringers or equivalent.

5005 The scantlings of cofferdam bulkheads not forming the boundary of a cargo tank are to be as required by D 19 for oil fuel deep tanks.

5006 Longitudinal bulkheads are to extend as far forward and aft as is practicable and are to be effectively scarphed to the adjoining structure.

PLANE BULKHEADS

Plating-Transverse Bulkheads

5007 The thickness of the plating is not to be less than

$$t = 0,004 \text{ s}\sqrt{h} + 2,5 \text{ mm}$$

$$(t = 0.0022 \text{ s}\sqrt{h} + 0.1 \text{ in})$$
and is in no case to be less than $\frac{s}{70}$

Plating-Longitudinal Bulkheads

5008 The thickness of plating is not to be less than that given in 5007 except that:—

(i) within 0,1D of the bottom shell the thickness of plating is not to be less than

$$t = 0.00425 \text{ s}\sqrt{h} + 2.5 \text{ mm}$$

 $(t = 0.00235 \text{ s}\sqrt{h} + 0.1 \text{ in})$

and is in no case to be less than $\frac{s}{55}$ with horizontal stiffening or $\frac{s}{40}$ with vertical stiffening.

(ii) within 0,1D of the deck the thickness of plating is not to be less than the thickness from (i) above less 1,5 mm (0.06 in), and is in no case to be less than s/5 with horizontal stiffening or s/40 with vertical stiffening.

For minimum thickness, see D 5309.

5009 Where the shear force has to be investigated (see D 4103) the thickness of the longitudinal bulkhead plating for 0,5D about mid-depth is to be as required by D 5007, or the following, whichever is the greater:—

$$t = \frac{F\left(0.34 - 0.075 \frac{A_s}{A_L}\right)}{D q} mm$$

$$\left(t = \frac{F\left(0.34 - 0.075 \frac{A_s}{A_L}\right)}{12 D q} in\right)$$

where F, As, Al and q are as given in D 4307.

Elsewhere, the thickness is not to be less than 90 per cent of that given above.

Stiffeners

5010 The section modulus of horizontal or vertical stiffeners is not to be less than:—

$$\begin{split} &\frac{\mathrm{I}}{\mathrm{y}} \!=\! \frac{\mathrm{s} \; \mathrm{S}^2}{117.5} \; (\mathrm{h}_1 + 0.9) \; \mathrm{cm}^3 \\ &\left(\frac{\mathrm{I}}{\mathrm{y}} \!=\! \frac{\mathrm{s} \; \mathrm{S}^2}{2680} \; (\mathrm{h}_1 + 3) \; \mathrm{in}^3 \right) \!, \end{split}$$

The section modulus given by this formula is that of the stiffener and associated plating. (See D 5302.)

5011 The modulus of horizontal stiffeners on longitudinal bulkheads is not to be less than 90 per cent of the modulus of the uppermost side longitudinal. These longitudinals are to comply with the requirements of D 4404.

5012 The modulus of vertical stiffeners on longitudinal or transverse bulkheads may be reduced by 10 per cent where vertical webs are fitted.

5013 Stiffeners are to be bracketed or otherwise efficiently connected at their ends to provide adequate fixity and, for horizontal stiffeners, continuity of longitudinal strength at the bulkheads.

The end brackets of longitudinal bulkhead vertical stiffeners are to be as required by Table D 57.5 and are to be connected to a suitable longitudinal or are to be well hollowed and tapered.

All stiffeners are to be connected to the supporting webs or girders as required by Table D 57.6.

The plating is to be efficiently stiffened to support loads transmitted by end connections of longitudinal bulkhead, shell and deck longitudinals and the like.

Webs and Girders

5014 The section modulus of vertical webs and horizontal girders is not to be less than that required by Table D 50.1.

For intercostal vertical webs not supporting stiffeners (item 2 in Table D 50.1) \mbox{D}_1 is to be taken as half the breadth of centre tank (or the breadth of wing tank) divided by the number of webs plus one (number of webs to be those in the half-breadth of centre tank or breadth of wing tank as appropriate) and S is to be measured between girders or from girder to span point. The maximum value of $6.9 \ \mbox{D}_1 \ \mbox{h}_1 \ \mbox{S}^2 \left(\frac{\mbox{D}_1 \ \mbox{h}_1 \ \mbox{S}^2}{275} \mbox{British} \right)$ is to be used for the full depth of bulkhead.

TABLE D 50.1

Item	Section Modulus, cm ³	Section Modulus, in
1. VERTICAL WEBS (other than in (2) below)		
(a) On transverse bulkheads not forming a ring system but including the web on the centre line.	12,65b h ₁ S ²	b h ₁ S ² 150
(b) On transverse bulkheads forming a ring system* (other than at centreline) as primary supporting members and supporting horizontal stiffeners.	10b h ₁ S ²	b h ₁ S ² 190
(c) On longitudinal bulkheads	as for side transverse	as for side transverse
2. Intercostal Vertical Webs on Transverse Bulkheads not Supporting Stif- feners	6,9b ₁ h ₁ S ²	b ₁ h ₁ S ² 275
3. Horizontal Girders on Longitudinal or Trans- verse Bulkheads		T LINE
(a) Single girder	11,9b h ₁ S ²	b h ₁ S ²
(b) Upper of two or more	14,6b h ₁ S ²	b h ₁ S ² 130
(c) Middle or lower	11,9b h ₁ S ²	b h ₁ S ² 160

• i.e., in association with bottom and deck girders of Rule scantlings

(See also 5015 to 5017).

5015 Where the distance between transverse bulk-heads (whether oiltight or non-oiltight) exceeds 24,5 m (80 ft), and continuous side girders are not fitted in the centre tank, the centreline vertical web is to be symmetrical on both sides of the transverse bulkhead.

5016 Where webs are symmetrical on each side of a plane bulkhead the section modulus derived as above may be reduced by 10 per cent.

5017 Where the breadth of a cargo tank exceeds 14 m (46 ft) the section modulus of the horizontal girders on the longitudinal bulkhead is to be increased at the rate of 2 per cent 0,3 m (1 ft) excess above 14 m (46 ft).

5018 Where side transverses are required by D 4504, vertical webs are to be fitted on the longitudinal bulkhead. Where vertical webs are not fitted, the lower horizontal girders are to be supported by suitable buttress brackets from the bottom transverses.

5019 The depth of a girder or web is not to be less than 2,5 times the depth of the slot for the stiffener.

For minimum thicknesses, see D 5309.

For moduli of webs and girders of various depths, face areas and bulkhead plating, see D 5306.

5020 The end attachments of vertical webs and horizontal girders are to have a length of arm at least equal to the depth of web.

CORRUGATED BULKHEADS

General

5021 Where corrugated bulkheads are adopted the corrugations should be arranged in accordance with 5002 and 5004.

5022 In ships above 180 m (590 ft) in length the upper and lower strakes of the longitudinal bulkhead are to be plane for a distance of 0,1D from the deck and bottom and the vertical webs are to be arranged symmetrically on each side of the longitudinal bulkhead. Alternative arrangements with unsymmetrical webs will be specially considered, having in view the spacing of transverses and the type of transverse bulkhead, etc.

Plating

5023 The thickness of plating of transverse and longitudinal bulkheads is not to be less than that required by 5007 and 5008 respectively.

The thickness of plating is also to be such that the requirements of 5024 are satisfied.

For minimum thickness, see D 5309.

5024 The minimum angle of corrugation is to be 40° and the dimensions of the corrugations are to fulfil the following conditions:—

$$\frac{\text{t d (3 b+c)}}{59 \text{ p}} \text{ not to be less than } h_1 S_1^2 \quad (1)$$

$$\frac{\text{t d}^2 (3 \text{ b+c})}{3800 \text{ p}} \text{ not to be less than h}_1 \text{ S}_1^3 (2)$$

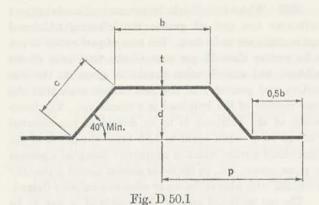
or in British units:-

$$\frac{\text{t d (3 b+c)}}{\text{p}}$$
 not to be less than $\frac{h_1 S_1^2}{385}$ (1)

$$\frac{\text{t d}^{2} (3 \text{ b+c})}{\text{p}} \text{ not to be less than } \frac{\text{h}_{1} \text{ S}_{1}^{3}}{500} (2)$$

where S₁ = span of corrugation, in metres (feet), measured from girder to girder, transverse to transverse or side, bottom, deck or bulkhead to transverse or girder,

and t, b, c, d and p in mm (in) are as shown in Fig. D 50.1.



In (1) and (2) above the value of b is not to be taken as greater than 50 t. Where unsymmetrical girders or webs are fitted to corrugated bulkheads, the maximum angle of corrugation is to be 60°.

5025 Where the shear force has to be investigated (see D 4103) the thickness of the longitudinal bulkhead plating is to be as required by 5023 and 5024 or 5009 whichever is the greater.

5026 Corrugations are to be in line, and of the same form, on each side of bulkheads, horizontal girders and vertical webs.

Webs and Girders

5027 Horizontal girders and vertical webs are to be arranged to support the corrugations. The spacing of transverses on longitudinal bulkheads is generally not to exceed 5 m (16.5 ft).

5028 The section modulus of vertical webs and horizontal girders is not to be less than that required by Table D 50.2.

For vertical webs forming a ring system and not supporting girders, b_1 is to be taken as half the breadth of the centre tank (or breadth of wing tank) divided by the number of webs plus one and S is to be measured between girders or from girder to span point. The maximum value of $6.9 \, b_1 \, h_1 \, S^2 \left(\frac{b_1 \, h_1 \, S^2}{275} \, British \right)$ is to be used for the full depth of bulkhead.

TABLE D 50.2

Item	Section Modulus, cm ³	Section Modulus, in
1. Vertical Webs (a) On Vertically Corrugated Bulkheads At centreline Other webs forming a ring system* and not sup- porting girders	12,65b h ₁ S ² 6,9b ₁ h ₁ S ²	b h ₁ S ² 150 b ₁ h ₁ S ² 275
(b) On Horizontally Corrugated Bulkheads		
(i) Transverse bulkheads: At centreline	12,65b h ₁ S ²	b h ₁ S ² 150
Other webs forming a ring system*	10b h ₁ S ²	b h ₁ S ² 190
Webs not forming a ring system	12,65b h ₁ S ²	b h ₁ S ² 150
(ii) Longitudinal bulkheads	as for side transverse	as for side transverse
2. Horizontal Girders on Vertically Corrugated Transverse Bulkheads		
(a) Single girder	11,9b h ₁ S ²	b h ₁ S ²
(b) Upper of two or more	14,6b h ₁ S ²	b h ₁ S ²
(c) Middle or lower	11,9b h ₁ S ²	130 b h ₁ S ² 160

i.e., in association with bottom and deck girders of Rule scantlings.
 (See also 5029 and 5030)

5029 Where the distance between transverse bulkheads (whether oiltight or non-oiltight) exceeds 25 m (82 ft), and continuous side girders are not fitted in the centre tank, the centreline vertical web is to be symmetrical on both sides of the transverse bulkhead.

5030 Where webs or girders are symmetrical on each side of a corrugated bulkhead the section modulus derived as above may be reduced by 10 per cent.

5031 For minimum thickness, see D 5309.

For moduli of webs and girders of various depths, face areas and bulkhead plating, see D 5306.

5032 The end attachments of vertical webs and horizontal girders are to have a length of arm at least equal to the depth of web.

NON-OILTIGHT BULKHEADS (PLANE OR CORRUGATED)

General

5033 Wash bulkheads and perforated centreline longitudinal bulkheads are to have an area of perforations not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the bulkheads act as an efficient girder, web or transverse and the lower part of a centreline bulkhead is to be adequately stiffened to act as a docking girder. See also 5039.

Where no continuous girders are fitted, consideration will be given to the omission of complete wash bulkheads provided suitable deep deck transverses are arranged.

Special care is to be taken to ensure that a perforated centreline longitudinal bulkhead provides an efficient connection between the deck and bottom plating.

Plating

5034 The thickness of plating may be the compartment minimum (see D 5309) except that the top and bottom strakes of a centreline bulkhead are to be as required by 5007 for an oiltight longitudinal bulkhead. See also 5039.

Stiffeners, Girders and Webs

5035 The section modulus of stiffeners and horizontal girders is to be not less than:—

$$\frac{\mathrm{I}}{\mathrm{y}} = \mathrm{k} \, \mathrm{s}_1 \, \mathrm{S}^2 \, \frac{\mathit{l}}{\mathrm{L}} \, \mathrm{cm}^3 \qquad \left(\frac{\mathrm{I}}{\mathrm{y}} = \mathrm{k} \, \mathrm{s}_1 \, \mathrm{S}^2 \, \frac{\mathit{l}}{\mathrm{L}} \, \mathrm{10}^{-4} \, \mathrm{in} \right) ,$$

where $k = 1215 \times 10^{-4}$ (175 British) for stiffeners on transverse bulkheads,

 3785×10^{-4} (545 British) for stiffeners on longitudinal bulkheads,

145 (2520 British) for girders on transverse bulkheads,

452 (7820 British) for girders on longitudinal bulkheads,

S₁ = spacing of stiffeners, in mm (in), or width of plating supported by girder, in metres (feet),

l = length or breadth, in metres (feet), of tank between oiltight bulkheads for transverse or longitudinal bulkheads respectively. Where two or more transverse wash bulkheads are fitted in one tank l is to be measured between the bulkheads adjacent to the wash bulkhead under consideration.

5036 The section modulus of vertical webs is to be not less than:—

On transverse bulkheads—the modulus required for an oiltight bulkhead multiplied by $\left(0.3+2\frac{l}{L}\right)$ where l is as defined in 5035.

On longitudinal bulkheads—50 per cent of that required for an oiltight bulkhead.

5037 The depth of webs and girders is to be at least 2,5 times the depth of the slot for the stiffener.

5038 When determining the width of plating supported and the effective area for calculating the modulus no deduction is to be made on account of perforations.

5039 Where non-oiltight transverse bulkheads support continuous fore and aft girders the following additional requirements are to be met. The area of perforation is not to be greater than 25 per cent of the total area of the bulkhead and consideration should be given to the disposition and geometry of the perforations such that the shear rigidity of the bulkhead is a maximum. The lower section of the bulkhead is to be devoid of non-essential openings for a depth equal to 1,75 times the depth of the longitudinal girders which it supports. Essential openings for pipes, access, etc., in the lower section should preferably be circular with edge stiffening or otherwise suitably framed.

The net sectional area of the bulkhead is not to be less than:—

$$A = \frac{n l_b b_t D}{1,85 (n+1)} cm^2 \qquad \left(A = \frac{n l_b b_t D}{420 (n+1)} in^2\right)$$

where l_{b} = half the distance between adjacent transverse support bulkheads forward and aft of the wash bulkhead under consideration, in metres (feet),

n = number of longitudinal continuous girders supported by bulkhead,

b_t = breadth of tank, in metres (feet).

The thickness of the plating may not be less than:-

$$t = \frac{a}{100 + 33 \frac{a}{b}}$$
 cm (in)

where a = least dimension of unstiffened plate panel, in cm (in).

b = greatest dimension of unstiffened plate panel in cm (in).

In no case should either panel dimension exceed 180t or that given by 5034.

Section 51

HATCHWAYS

Oiltight Hatchways

5101 Oiltight hatchways are to be kept to the minimum size required to provide reasonable access and ventilation to each compartment.

Corners of hatchway openings are to be well rounded and smooth.

5102 The height of the coaming is not to be less than 250 mm (9.84 in). Coaming plates not exceeding 820 mm (32 in) in height are not to be less than 10 mm (0.40 in) in thickness.

5103 Where the area of the hatchway cover does not exceed 1,2 m^2 (13 ft²) in a circular hatchway, or 1,5 m^2 (16 ft²) in a rectangular hatchway, the thickness of the cover is to be 12,5 mm (0.50 in).

If the area exceeds the above but does not exceed 2.4 m^2 (26 ft²) the thickness of the cover is to be 15 mm (0.60 in) or may be 12,5 mm (0.50 in) if stiffened by 100 mm (4 in) flats spaced 610 mm (24 in) apart.

5104 Covers are to be secured by fastenings spaced not more than 457 mm (18 in) apart in a circular hatchway or 380 mm (15 in) apart in a rectangular hatchway and not more than 230 mm (9 in) from the corners.

Hatchway covers of special design with alternative methods of closing will be specially considered.

Ullage Plugs and Tank Cleaning Openings

5105 Ullage plugs, sighting ports and tank cleaning openings are not to be arranged in enclosed spaces.

Access to Cofferdams, Dry Tanks or Water Ballast Tanks

5106 If hatchways are provided for access to these spaces the requirements of 5101 to 5104 are to be complied with.

5107 Access may be by a watertight manhole provided the plate cover is not less than 12,5 mm (0.50 in) in thickness and the bolts are not more than 100 mm (4 in) apart.

Hatchways to Spaces other than Oil Tanks, Cofferdams, Dry Tanks, or Water Ballast Tanks

5108 Hatchways are to be constructed in accordance with the requirements of D 26, except that efficient steel watertight covers are to be fitted to hatchways situated on expansion trunks and on the strength deck, either where exposed or inside open superstructures.

Hatchways situated on the forecastle deck are to have steel covers, except where efficient steel watertight covers are fitted to the hatchways inside the forecastle.

Section 52

TESTING

General

5201 Each cargo tank and cofferdam is to be separately tested by filling with water to the test head.

When water testing on the building berth or in drydock may be undesirable, testing may be carried out afloat, provided any riveted shell seams in the bottom and bilge plating are tested with a high pressure hose test on the berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head. With about half the number of tanks full, the bottom and lower side shell in the empty tanks is to be examined and the remainder of the bottom and lower side shell examined when the water is transferred.

When a preservative coating is to be applied to the internal structure of a tank, the water testing may take place after the application of the preservative, provided the structure is carefully examined to ensure that all welding and structural stiffening is completed prior to the application of the coating and any riveted shell seams are tested with a high pressure hose test on the berth before coating. The hose test of the riveted seams may be carried out from the outside to avoid wetting the tank structure.

The cause of any discoloration or disturbance of the coating is to be ascertained and any deficiencies repaired.

5202 In lieu of the complete water testing required by 5201 a combination of a leak test and a structural test may be adopted.

The leak test is to be carried out on each tank while the vessel is on the building berth; it is to consist of a soapy solution test made while the tank is subjected to an air pressure of 0,14 kg/cm² (2 lb/in²). It is recommended that the air pressure in the tank be raised to 0,21 kg/cm² (3 lb/in²) with the minimum number of personnel in the vicinity of the tank and lowered to the test pressure before inspection commences.

A structural test is to be applied to one centre and two side tanks (to be selected by the Surveyor) by water testing to the test head (see 5205).

Air testing is to be carried out before a protective coating is applied.

5203 Water ballast and dry tanks should be tested as required for cargo tanks.

5204 It is recommended that pump rooms be flooded to a suitable depth prior to launch. The bottom and side shell plating is to be carefully examined internally with the vessel at a deep draught. Bulkheads not forming tank boundaries are to be hose tested.

Test Head

5205 The test head for cargo tanks is to be 2,45 m (8 ft) above the highest point of the tank, excluding hatchways; that for cofferdams is to be to the top of the hatchway.

Bunkers and Deep Tanks

5206 Bunkers and deep tanks are to be tested as required by D 1933.

Section 53

EFFECTIVE SECTION MODULUS, FACE AREAS AND MINIMUM THICKNESSES

Symbols

5301

L = length of ship, in metres (feet),

d = depth of girder, etc., in mm (in), between inside of face plate and attached plating or for symmetrical girders between inside of face plates. Where a girder, etc., is at right angles to a line of corrugations the minimum depth is to be taken,

tp = mean thickness of attached shell, deck or bulkhead plating, in mm (in),

tw = thickness of web, in mm (in).

EFFECTIVE SECTION MODULUS

Longitudinals, Frames and Stiffeners

5302 For longitudinals, side frames and bulkhead stiffeners the section modulus required by the appropriate formula is to be that of the section in association with 610 mm (24 in) of plating having the same thickness as the shell, deck or bulkhead plating as appropriate. Where the attached plating is of varying thickness, the mean thickness over the appropriate span is to be used.

The effective section moduli of rolled sections and the area of the section without plating are given in the publication "Geometric Properties of Rolled Sections and Built Girders".

The effective section moduli of flat bars or built sections may be obtained from curves in the above publication.

Transverses, Webs, Stringers and Girders

5303 For transverses, webs, stringers and girders, the section modulus required by the appropriate formula is to be that of the member in association with an effective area of shell, deck or bulkhead plating.

5304 Except for corrugated bulkheads, the effective area is to be:—

$$A = 10 \text{ k } b \text{ t}_{\text{p}} \text{ cm}^2 \text{ (A} = 12 \text{ k } b \text{ t}_{\text{p}} \text{ in}^2),$$

where k = a coefficient obtained from Table D 53.1,

b = actual width, in metres (feet), of load-bearing plating, i.e., one-half the sum of spacings of parallel adjacent members of greater or equivalent length (see Fig. D 53.1),

l = overall length of girder, transverse, etc., in metres (feet) (see Fig. D 53.1).

TABLE D 53.1

$\frac{l}{b}$	0,5	1,0	2,0	3,0	4,0	5,0	6,0
k	0,12	0,23	0,45	0,67	0,80	0,90	1,00

For intermediate values of $\frac{l}{b}$, k is to be obtained by interpolation. Where $\frac{l}{b}$ exceeds 6,0, k is to be taken as 1,0.

 ${\bf 5305}$. For corrugated bulkheads the effective area is to be:—

(a) for girders, etc., at right angles to the direction of corrugations:

A = area of face plate in cm2 (in2) (see also 5308),

(b) for girders, etc., parallel to the direction of corrugations:

$$A = \frac{b_C t_p}{100} cm^2$$
 $(A = b_C t_p in^2),$

where b_C = breadth, in mm (in), of flat panel of corrugated bulkhead.

5306 The effective section modulus of any transverse, web, stringer or girder is given by:—

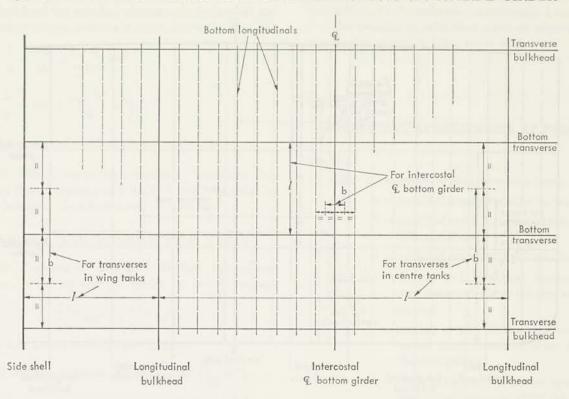
$$\frac{I}{y} = \frac{ad}{10} + \frac{t_W d^2}{6000} \left[1 + \frac{200 (A - a)}{200 A + t_W d} \right] cm^3 (1)$$

$$\bigg(\begin{array}{c} \frac{\mathrm{I}}{\mathrm{y}} = \mathrm{ad} + \begin{array}{c} \mathrm{t_w} \ \mathrm{d}^2 \Big[\ 1 + \frac{\mathrm{A} - \mathrm{a}}{\mathrm{A} + 0.5 \ \mathrm{t_w} \ \mathrm{d}} \Big] \ \mathrm{in}^3 \bigg), \end{array}$$

where a = area of face plate, in cm2 (in2).

Where the effective area A derived in accordance with 5304 or 5305 is less than the face area, A is to be taken as equal to a.

(a) BOTTOM STRUCTURE WITH INTERCOSTAL BOTTOM CENTRELINE GIRDER



(b) BOTTOM STRUCTURE WITH CONTINUOUS BOTTOM CENTRELINE GIRDER

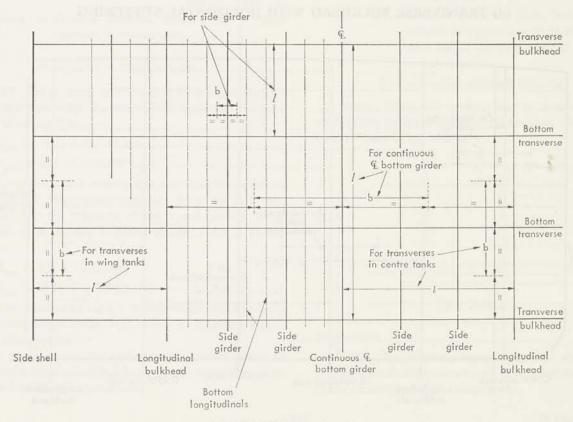
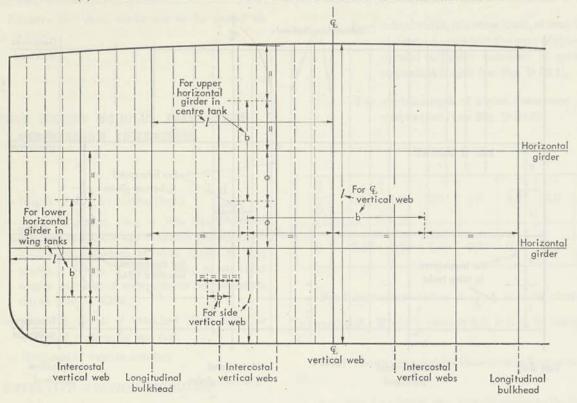


Fig. D 53.1 (see continuation)

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(c) TRANSVERSE BULKHEAD WITH VERTICAL STIFFENING



(d) TRANSVERSE BULKHEAD WITH HORIZONTAL STIFFENING

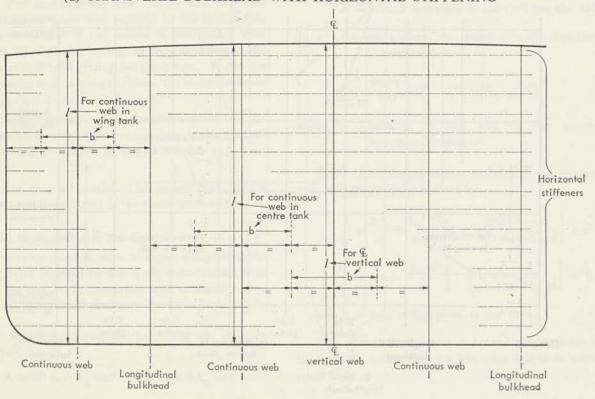


Fig. D 53.1 (concluded)

For girders, etc., which are symmetrical on each side of the bulkhead the attached plating is to be ignored and the effective section modulus is given by:—

$$\frac{I}{y} = \frac{ad}{10} + \frac{t_w d^2}{6000} cm^3 \tag{2}$$

$$\Big(\;\frac{\text{I}}{\text{y}}=\text{ad}+\frac{\text{t}_{\text{W}}\;\text{d}^2}{6}\,\text{in}^3\Big)\text{,}$$

where a = area of one face plate in cm2 (in2).

5307 The curves in the publication "Geometric Properties of Rolled Sections and Built Girders" may also be used to determine the effective section modulus.

MAXIMUM AND MINIMUM FACE AREAS

5308 The area of material in the face plate of any transverse, web, stringer or girder is not to exceed

$$\frac{\text{d}~t_\text{W}}{150}~\text{cm}^\text{2}~~ \left(\frac{\text{d}~t_\text{W}}{1{\cdot}5}~\text{in}^\text{2}\right).$$

The face area is not to be less than:

(a) bottom centreline girder
$$\frac{l}{60}$$
 cm² $\left(\frac{l}{50}$ in² $\right)$

(b) other transverses, girders, etc.,
$$\frac{l}{240}$$
 cm² $\left(\frac{l}{200}$ in² $\right)$

where I = distance between docking or tripping brackets, in metres (feet).

MINIMUM THICKNESS

5309 For ships up to 200 m (656 ft) in length no part of the structure within the range of the cargo tanks is to be less in thickness than:—

$$\rm t_{min} = ~6,85 + 0,024L~mm$$

$$(t_{min} = 0.27 + 0.00029L in)$$

When, however, L exceeds 200 m (656 ft) the minimum thickness for non-primary members is to be 11,5 mm (0.46 in), but the thickness of transverses, girders, webs, stringers, cross ties and bulkhead plating is not to be less than:—

$$t_{min} = 9.5 + 0.01 L mm$$

$$(t_{min} = 0.38 + 0.00012L in)$$

These minima also apply to cofferdams at the ends of, or between, cargo tanks, but, except as indicated below, not to pump rooms.

In pump rooms the minimum thicknesses apply to shell, decks, longitudinal bulkheads and to the bottom, side, deck and bulkhead longitudinals, For other items solely within these spaces the minimum derived from the formulæ may be reduced by 1 mm (0.04 in).

For permissible reductions when an approved system of corrosion control is fitted, see D 4016.

Section 54

STRUCTURAL ARRANGEMENTS AT FORE END

Symbols

5401 L = length of ship, in metres (feet).

B = moulded breadth of ship, in metres (feet).

D = moulded depth, in metres (feet), to deck at side amidships.

d = moulded draught, in metres (feet).

S = frame or longitudinal spacing, in mm (in), measured along the line of the shell plating.

S₁ = spacing of web frames or transverses, in metres (feet), measured along the line of the shell plating.

S = span, in metres (feet), from span point to span point, measured along the line of the shell plating.

h = distance, in metres (feet), from mid-point of span to a point 3 m (9.84 ft) above the deck height obtained from D 1702 unless stated otherwise.

C = a constant obtained from Fig. D 54.1.

Note. Spans and spacings may be measured along a straight line joining the ends of the member. Slopes smaller than 10° may be ignored.

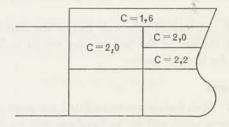


Fig. D 54.1

Construction

5402 The following requirements are applicable to tankers framed either transversely or longitudinally forward of the forward end of the cargo tanks.

If a combination of transverse and longitudinal framing is adopted equivalent strength is to be provided.

A centreline bulkhead, which may be non-oiltight, is to be fitted in the deep tank, or the longitudinal bulkheads are to extend forward to the forward deep tank bulkhead.

TRANSVERSE FRAMING SYSTEM

CONSTRUCTION IN WAY OF DEEP TANKS

Frame Spacing

5403 The frame spacing in deep tanks is not, in general, to exceed 700 mm (27.5 in) where D is greater than 8.9 m (29 ft) and $\frac{1000 \text{ D}}{24} + 330 \text{ mm} \left(\frac{\text{D}}{2} + 13 \text{ in}\right)$ where D is less than 8.9 m (29 ft).

Bottom Construction

5404 Floors are to be fitted at every frame. They are to have a minimum depth at the centreline of:—

$$\frac{1000D}{12} + 150 \text{ mm}$$
 (D + 6 in)

and a thickness of not less than:-

$$t = 0.666D + 2 mm$$
 (t = 0.008 D + 0.08 in)

but the thickness of the floors need not exceed 11,5 mm (0.46 in), and the depth of the floors need not exceed 1400 mm (55 in), but see also 5406.

Floors are to be adequately stiffened and the area of the face bar on the upper edge of the floors is not to be less

than:
$$\frac{B}{1,18}$$
 cm² $\left(\frac{B}{25} \text{ in}^2\right)$.

5405 Intercostal side girders are to be fitted between the floors, in line with alternate bottom longitudinals in the forward cargo tanks, and are to be extended as far forward as practicable. They are to have the same depth as the floors.

5406 In way of side web frames the depth of the floor and the size of the face bar are not to be less than required for the web frame.

Web Frames

5407 Web frames are to be fitted not more than five frame spaces apart and are to have a section modulus not less than:—

$$\frac{I}{y} = 9 \; s_1 \; h \; S^2 \; cm^3 \qquad \left(\frac{I}{y} = \frac{s_1 \; h \; S^2}{210} \, in^3 \right)$$

but h is not to be taken as less than the distance from the mid-point of span to the highest point of the tank, excluding the hatchway.

Side Stringers

5408 Horizontal side stringers are to be arranged in the deep tank in line with the stringers in the fore peak and are to have section moduli not less than:—

(1) supporting stringers which are to be in line with alternate fore peak stringers:—

$$\frac{I}{y} = 33.2 \text{ h s}_1^2 \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{\text{h s}_1^2}{17 \cdot 5} \text{ in}^3\right)$$

and (2) intermediate stringers:-

$$\frac{I}{y} = 23.3 \text{ h s}_{1}^{2} \text{ cm}^{3} \qquad \left(\frac{I}{y} = \frac{\text{h s}_{1}^{2}}{25} \text{ in}^{3}\right)$$

but h is not to be taken as less than the distance from the stringer to the highest point of the tank, excluding the hatchway.

Side Framing

5409 Deep tank side frames are to be determined in accordance with D 721 with H measured between the supporting stringers, see 5408(1).

Deep Tanks Extending to Uppermost Continuous Deck

5410 For additional requirements when deep tanks extend to the uppermost continuous deck, see 5439.

CONSTRUCTION IN DRY CARGO HOLD ABOVE DEEP TANKS

Web Frames

5411 Web frames are to be fitted in the dry cargo hold in line with those in the deep tank below and are to have a section modulus not less than:—

$$\frac{\mathrm{I}}{\mathrm{y}} = 1,68 \; \mathrm{C} \; \mathrm{s_i} \; \mathrm{h_i} \; \mathrm{d} \; \sqrt{\mathrm{D}} \; \mathrm{cm}^3$$

$$\left(\frac{I}{y} = \frac{C s_1 h_1 d \sqrt{D}}{625} in^3\right)$$

where h, = 'tween deck height, in metres (feet).

Side Stringers

5412 Side stringers are to be fitted in dry cargo holds, spaced about 2,5 m (8·2 ft) apart and are to have the same depth as the frame. The minimum thickness of the intercostal plate web is to be 8,5 mm (0·34 in) and the area of the face plate is to be:—

$$\frac{L}{7} + 6 \text{ cm}^2$$
 $\left(\frac{L}{150} + 1 \text{ in}^2\right)$

Framing

5413 Frames in dry cargo holds above deep tanks are to be determined in accordance with D 707 but ignoring the panting factor "f" in Fig. D 7.3.

CONSTRUCTION IN FORE PEAKS

Framing

5414 The frames in the fore peak are generally to be spaced 610 mm (24 in) apart and are to be determined in accordance with D 713 and to have a vertical extent not less than required by Fig. D 7.3.

Floors

5415 Floors are to be fitted at every frame, and are to have a depth and thickness not less than required by 5404, and their free edges are to be suitably stiffened.

Panting Beams

5416 Tiers of panting beams are to be fitted on alternate frames in the fore peak, spaced not more than 2,0 m (6.56 ft) apart. They are to have scantlings in accordance with D 1103.

5417 If desired, an arrangement incorporating perforated flats in lieu of tiers of panting beams may be adopted. These may be spaced 2,5 m ($8\cdot2$ ft) apart and are to have scantlings as required by 5439(1).

Side Stringers

5418 Side stringers determined in accordance with D 1106 are to be fitted at each tier of panting beams.

'Tween Decks Above Fore Peaks

5419 Frames in 'tween decks above fore peaks are to be determined in accordance with D 707.

LONGITUDINAL FRAMING SYSTEM

CONSTRUCTION IN WAY OF DEEP TANKS

Bottom Transverses

5420 Bottom transverses in deep tanks are to be spaced not more than 3 m (9.84 ft) apart and are to have a section modulus in accordance with D 4603.

Bottom Longitudinals

5421 Bottom longitudinals are to be fitted in line with those in the cargo tanks and are to have a section modulus in accordance with D 4402.

Side Girders

5422 An intercostal side girder, which is to have the same depth as the bottom transverses, is to be fitted each side of the centreline.

Centreline Girder

5423 Where the cargo tank longitudinal bulkheads are extended forward into the deep tanks and the centreline bulkhead is omitted, a centre girder having a section modulus in accordance with D 4805 is to be fitted.

Side Transverses

5424 Side transverses are to be spaced not more than 3.0 m (9.84 ft) apart and are to have a section modulus not less than:—

$$\frac{I}{y} = 9 \text{ s}_1 \text{ h S}^2 \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{\text{s}_1 \text{ h S}^2}{210} \text{ in}^3\right)$$

Side transverses are to be in line with forecastle deck transverses.

Side Longitudinals

5425 The section modulus of the side longitudinals is not to be less than given by the following formula, or by D 4402, whichever is the greater:—

$$\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{s} \; \mathrm{h} \; \mathrm{S}^2}{132} \; \mathrm{cm}^3 \qquad \left(\frac{\mathrm{I}}{\mathrm{y}} = \frac{\mathrm{s} \; \mathrm{h} \; \mathrm{S}^2}{3000} \; \mathrm{in}^3\right)$$

Deep Tank Extending to Uppermost Continuous Deck

5426 For additional requirements when deep tanks extend to the uppermost continuous deck, see 5439.

CONSTRUCTION IN DRY CARGO HOLDS ABOVE DEEP TANKS

Side Transverses

5427 Side transverses in the dry cargo hold are to be in line with those in the deep tank below and are to have a section modulus not less than:—

$$\begin{split} \frac{\mathrm{I}}{\mathrm{y}} &= 2.3 \, \mathrm{C} \, \mathrm{s_1} \, \mathrm{h_1} \, \mathrm{d} \, \sqrt{\mathrm{D}} \, \mathrm{cm}^3 \\ \left(\frac{\mathrm{I}}{\mathrm{y}} &= \frac{\mathrm{C} \, \mathrm{s_1} \, \mathrm{h_1} \, \mathrm{d} \, \sqrt{\mathrm{D}}}{450} \, \, \mathrm{in}^3 \, \right) \end{split}$$

where h, = 'tween deck height, in metres (feet).

Side Longitudinals

5428 The section modulus of side longitudinals in cargo holds above deep tanks is to be in accordance with 5425.

CONSTRUCTION IN FORE PEAKS

Bottom Construction

5429 Floors, which are generally to be spaced 610 mm (24 in) apart, are to have a depth and thickness not less than required by 5404 and their free edges are to be suitably stiffened.

Side Transverses

5430 Side transverses are to be spaced not more than 2,5 m (8·2 ft) apart and are to have a section modulus not less than:—

$$\frac{I}{y} = 9 \text{ s}_1 \text{ h S}^2 \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{\text{s}_1 \text{ h S}^2}{210} \text{ in}^3\right)$$

In order to provide adequate end fixity for the side transverses, suitable transverses are to be arranged under the deck or flat in way of the side transverses, and the depth of floor in way is not to be less than that of the side transverse. The face bar of the transverse is to be continuous along the upper edge of the floor.

5431 If perforated flats are fitted to support the side transverses their scantlings are to be in accordance with 5439(1).

Side Longitudinals

5432 Fore peak side longitudinals are to have a section modulus not less than that required by 5425.

TWEEN DECKS ABOVE FORE PEAKS

Side Transverses

5433 Side transverses in 'tween decks above fore peaks are to be in line with the peak side transverses and are to have a section modulus not less than required by 5427.

Side Longitudinals

5434 The section modulus of side longitudinals is to be in accordance with 5425.

Forecastles

5435 Web frames supporting side longitudinals are to have a section modulus not less than:—

$$\begin{split} \frac{\mathrm{I}}{\mathrm{y}} &= 2.1 \; \mathrm{C} \; \mathrm{s_1} \; \mathrm{h} \; \mathrm{d} \; \sqrt{\mathrm{D}} \; \mathrm{cm}^3 \\ \left(\frac{\mathrm{I}}{\mathrm{v}} &= \frac{\mathrm{C} \; \mathrm{s_1} \; \mathrm{h} \; \mathrm{d} \sqrt{\mathrm{D}}}{500} \; \mathrm{in}^3 \right) \end{split}$$

but h is not to be taken as less than the distance from the mid-point of span to the forecastle deck at side.

Their depth is not to be less than twice that of the longitudinals.

5436 Side longitudinals in the forecastle are to have a section modulus not less than:—

$$\begin{split} \frac{I}{y} &= \frac{\text{s S}^2}{132} \left(0.6 + \frac{\text{D}}{6} \right) \text{ cm}^3 \\ \left(\frac{I}{y} &= \frac{\text{s S}^2}{3000} \left(2 + \frac{\text{D}}{6} \right) \text{ in}^3 \right) \end{split}$$

5437 Pillars supporting the forecastle deck are, in general, to be spaced not more than 3,7 m (12·1 ft) apart in the region forward of 0.04 L abaft the forward perpendicular.

GENERAL

5438 The required section modulus of members attached to the shell is to be obtained about an axis parallel to the attached plating.

Deep Tanks Extending to Uppermost Continuous Deck

5439 Where in ships exceeding 180 m (590 ft) in length, the deep tanks extend to the uppermost continuous deck and a centreline bulkhead only is fitted, the web frames and side transverses, which are to be in accordance with 5407 and 5424 respectively, are to be supported by one of the following methods:—

- (1) One or more perforated flats having a thickness not less than 9 mm (0·35 in) and an area of perforations not less than 10 per cent of the total area of the flat. The section modulus of the girders and beams or longitudinals on the flats may be 50 per cent of that required for an intact flat in the same position. Suitable transverses are to be arranged under the flats in way of the side transverses,
- (2) One or more heavy side stringers having a section modulus not less than:—

$$\frac{I}{y} = 12,6 \text{ b h S}^2 \text{ cm}^3$$
 $\left(\frac{I}{y} = \frac{\text{b h S}^2}{150} \text{ in}^3\right)$

where b = breadth supported by the stringer, in metres (feet),

but h is not to be taken as less than the distance from the mid-point of span to the highest point of the tank, excluding the hatchway.

The ends of the stringers are to be connected to suitable stringers on the transverse bulkheads,

- (3) Cross ties having scantlings required by D 4901 and having a vertical strut fitted at about mid-length. The dimensions of the strut are to be not less than those of the uppermost cross tie and it is to be effectively connected to the deck and bottom transverse and cross ties.
- (4) Cross ties having scantlings required by D 4901 and having one or more fore and aft horizontal struts arranged to brace the cross ties between the deep tank bulkheads. The struts are to have a size appropriate to the cross ties supported.
- 5440 Where the longitudinal bulkheads are carried forward in deep tanks extending to the upper deck, the scantlings are to be as required by D46, D48 and D49.

Bulbous Bows

- 5441 The constructional arrangements required are dependent upon the shape and size of the bulb but, in general, the arrangement is to incorporate the following items:—
 - (i) Large bulbous bows are to have a centreline wash bulkhead and horizontal diaphragm plates spaced not more than 1 m (3·28 ft) apart at the fore end of the bulb.
 - (ii) Small bulbous bows need not have a centreline wash bulkhead but are to have horizontal diaphragm plates spaced not more than 1 m (3·28 ft) apart; normally these are to be in conjunction with a centreline web.

Where the length or width of a fore peak is unusually great due to fitting a bulbous bow, additional strengthening in the form of a transverse wash bulkhead at the midlength of the peak-bulb space, may be required.

The shell plating in way of the bulb is, in general, to have a thickness required by D 1205. This increased plating should be extended to cover the areas likely to be damaged by the anchor and chain cables.

Continuity of Strength

5442 Continuity of strength is to be maintained at the scarphing of longitudinal and transverse framing and in cofferdams.

Construction of Bulkheads

5443 The scantlings of deep tank and peak tank bulkheads are to be in accordance with D 19, as applicable. For cofferdam bulkheads, see also D 5309.

Construction of Deep Tank Top

5444 The scantlings and arrangements of the deep tank top are to be as required by D 1919 and D 1920.

Cross-reference

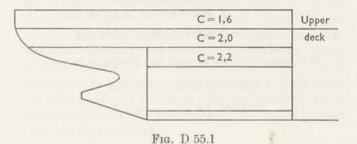
5445 For structural details, see D 57.

Section 55

STRUCTURAL ARRANGEMENTS AT THE AFTER END

5501 Symbols

- L = length of ship, in metres (feet).
- B = moulded breadth of ship, in metres (feet).
- D = moulded depth, in metres (feet), to deck at side amidships.
- $D_1 =$ moulded depth, in metres (feet), but not to be taken as greater than 20 m (65 · 6 ft).
- d = moulded draught, in metres (feet).
- S = frame or longitudinal spacing, in mm (inches).
- S₁ = spacing of web frames or stringers, in metres (feet).
- S = span, in metres (feet).
- h = distance, in metres (feet), from mid-point of span to upper deck at side amidships, unless stated otherwise.
- C = a constant obtained from Fig. D 55.1.



Construction

5502 Aft of the forward machinery space bulkhead the requirements contained in the following sections are applicable to transverse or longitudinal systems of framing as appropriate. If a combination of these arrangements is adopted equivalent strength is to be provided.

Double Bottom

5503 The double bottom is to be transversely framed. The scantlings and arrangements of the double bottom in way of the main propulsion machinery are to be suitable for its type and power. Sufficient fore and aft girders should be arranged to effectively distribute the weight of the machinery and ensure adequate rigidity, and they are to

extend aft under the thrust block seat. The tank top in way of the engine foundation should be substantially increased in thickness. The main engine seating should, in general, be integral with the double bottom structure; this particularly applies to higher power diesel and turbine installations. The general scantlings of the double bottom clear of the main machinery are to be not less than as follows:—

Minimum depth of centre girder DDB =

$$\frac{1000~\text{B}}{36} + 205~\sqrt{\text{d}}~\text{mm} \qquad \Big(\,\frac{\text{B}}{3} + 4\cdot5~\sqrt{\text{d}}~\text{in}\,\Big).$$

Thickness of centre girder =

but may be 10 per cent less at aft end where clear of main engine seating.

Thickness of non-watertight floors and side girders = $0.008 \, D_{DB} + 1 \, \text{mm}$ (0.008 $D_{DB} + 0.04 \, \text{in}$).

Thickness of watertight floors = non-watertight thickness + 2 mm (0.08 in) but need not exceed 15 mm (0.59 in).

 $\frac{\mathbf{I}}{\mathbf{y}}$ of watertight floor stiffeners =

$$\frac{\mathsf{D^2_{DB}\,h_{DB}\,s_{DB}\,cm^3}}{185\times10^6}\,\mathrm{cm^3}\qquad \left(\frac{\mathsf{D^2_{DB}\,h_{DB}\,s_{DB}\,in^3}}{600\,000}\right)$$

where D_{DB} = depth of double bottom, in mm (in),

h_{DB} = head from top of inner bottom to top
of overflow pipe, in metres (feet),

s_{DB} = stiffener spacing, in mm (in).

Minimum thickness of tank top plating is to be:-

$$0,0015 \sqrt[4]{\text{Ld (s + 660) mm}}$$

 $(0.00085 \sqrt[4]{\text{Ld (s + 26) in)}}$.

TRANSVERSE FRAMING SYSTEM

Framing

5504 Main frames in the engine room are to have a section modulus in accordance with D 707(1).

5505 'Tween deck and poop side frames are to have a section modulus in accordance with D 707(1). Where horizontal stringers having scantlings required by 5508 are fitted, they may be considered to be decks for the purpose of calculating the required frame section modulus.

5506 Aft of the line of the after peak bulkhead, peak and 'tween deck frames are to be spaced as required by D 706. Peak frames are to have a section modulus in

accordance with D 713 and 'tween deck and poop frames aft of the line of the after peak bulkhead are to have a section modulus in accordance with D 707(3).

Web Frame and Side Stringers

5507 Web frames are to be fitted in the machinery space below the lowest deck or flat, not more than five frame spaces apart.

5508 Where a horizontal stringer giving full support to the side framing is fitted below the lowest deck or flat, the web frame section modulus is to be based on a stress of 9,5 kg/mm² (6 ton/in²), assuming fixed ends and point loading from the stringer, taking the head to upper deck at side amidships.

The section modulus of the stringer is not to be less than:—

$$7,75 \, \mathrm{S_1} \, \mathrm{h} \, \mathrm{S^2 \, cm^3} \qquad \left(\frac{\mathrm{S_1} \, \mathrm{h} \, \mathrm{S^2}}{245} \, \mathrm{in^3} \right)$$

5509 Where a horizontal stringer giving partial support to the side framing is fitted below the lowest deck or flat, the web frames are to have a section modulus not less than:—

$$7,75 \, \mathrm{S_1} \, \mathrm{h} \, \mathrm{S^2 \, cm^3} \qquad \left(\frac{\mathrm{S_1} \, \mathrm{h} \, \mathrm{S^2}}{245} \, \mathrm{in^3} \right)$$

The section modulus of the stringer is not to be less than:—

$$3.8 \, \mathrm{S}_1 \, \mathrm{h} \, \mathrm{S}^2 \, \mathrm{cm}^3$$
 $\left(\frac{\mathrm{S}_1 \, \mathrm{h} \, \mathrm{S}^2}{500} \, \mathrm{in}^3 \right)$

5510 Where no stringer is fitted the section modulus of the web frames is not to be less than:—

$$5.0 \, \text{S}_1 \, \text{h} \, \text{S}^2 \, \text{cm}^3$$
 $\left(\frac{\text{S}_1 \, \text{h} \, \text{S}^2}{380} \, \text{in}^3\right)$

5511 The minimum depth of web frames in 5508, 5509 and 5510 is not to be less than 2,5 times the depth of the adjacent side frames.

The thicknesses of web frames and horizontal stringer webs are to be the same.

5512 Above the lowest deck, or equivalent, webs are to be fitted in line with the web frames below the deck and are to extend to the uppermost continuous deck. The section modulus of these web frames is not to be less than:—

1,67 C s₁ S d
$$\sqrt{D}$$
 cm³ $\left(\frac{\text{C s}_1 \text{ S d } \sqrt{D}}{625} \text{ in}^3\right)$

Where there is no midship erection and all accommodation is fitted aft, sufficient web frames or partial bulkheads are to be fitted in the poop and in the superstructure above to ensure adequate transverse rigidity.

These webs should, in general, be in line with the web frames below the upper deck.

LONGITUDINAL FRAMING SYSTEM

Longitudinal Framing in Machinery Space

5513 In the machinery space the section modulus of the side longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{\text{s S}^2}{153,5} \left(h + \frac{D_1}{6} \right) \text{cm}^3 \quad \left(\frac{I}{y} = \frac{\text{s S}^2}{3500} \left(h + \frac{D_1}{6} \right) \text{in}^3 \right)$$

where h is not to be less than 0,9 m (3 ft).

Web Frames

5514 The section modulus of transverse webs in machinery spaces situated below the lowest deck or equivalent flat and supporting side longitudinals is not to be less than:—

$$\frac{I}{y} = 10 \, s_1 \, h \, S^2 \, cm^3$$
 $\left(\frac{I}{y} = \frac{s_1 \, h \, S^2}{190} in^3 \right)$

The spacing of web frames is not to be more than required by 5507.

5515 Above the lowest deck or equivalent, webs are to be fitted in line with the web frames below the deck and are to extend to the uppermost continuous deck. The section modulus of the web frames is not to be less than:—

$$\frac{\mathrm{I}}{\mathrm{y}} = 2.1~\mathrm{C~s_1~S~d~\sqrt{D~cm^3}}$$

$$\left(\frac{I}{y} = \frac{C s_1 S d \sqrt{D}}{500} in^3\right)$$

5516 When longitudinal framing is adopted above the after peak, transverse webs are to be fitted in the 'tween decks not more than four frame spaces apart. The section modulus of these webs is not to be less than:—

$$\frac{1}{y} = 2$$
,1 C s₁ S d \sqrt{D} cm³

$$\left(\frac{I}{y} = \frac{C \, s_1 \, S \, d \sqrt{D}}{500} \, \operatorname{in}^3\right)$$

5517 The section modulus of side longitudinals above the after peak and abaft the after peak bulkhead is not to be less than:—

$$\frac{I}{y} = \frac{\text{S S}^2}{117,5} \left(h + \frac{D_i}{6} \right) \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s S^2}{2680} \left(h + \frac{D_1}{6}\right) in^3\right)$$

where h is not to be less than 3 m (9.84 ft). Where, due to the shape of the vessel, the spacing of longitudinal exceeds 915 mm (36 in), intermediate longitudinals are to be fitted.

Poop Side Longitudinals

5518 Poop side longitudinals are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{\text{S S}^2}{153,5} \left(0.6 + \frac{\text{D}_1}{6} \right) \text{cm}^3$$

$$\left(\frac{1}{V} = \frac{\text{S S}^2}{3500} \left(2 + \frac{\text{D}_1}{6}\right) \text{in}^3\right)$$

GENERAL

After Peak

5519 Floors in the after peak and counter are to have a thickness not less than that required by 5503. They are to be stiffened by flat bars or rolled sections of adequate size and spacing, bearing in mind possible vibratory forces which may arise in this region from the propeller. A centreline wash bulkhead having the same thickness as the floors is to be arranged in the after peak tank and counter. When transverse framing in accordance with 5505 is fitted above the after peak, web frames or their equivalent are to be arranged in the 'tween decks at every fourth frame abaft the after peak bulkhead.

5520 Frames, floors, stringers, girders, stiffeners and wash bulkheads in the after peak, or on the after peak bulkhead are not to be scalloped and the connection to shell or bulkhead is to be by double continuous welds.

Decks

5521 Lower decks or flats are to have sufficient strength and adequate end fixity when they are intended to support webs and side frames.

Strong Beams and Pillars

5522 Strong beams or other efficient cross ties are, in general, to be fitted in way of large machinery openings and are to be associated with suitable web frames. An efficient

pillaring system is to be provided under the engine casing and the casing sides are to be suitably stiffened in way of pillars. When the casing is used as a supporting girder suitable compensation is to be provided for openings.

Oil Fuel Bunkers

5523 The structural arrangements in the cargo tanks are to be maintained in oil fuel bunkers at the fore end of the machinery space. The scantlings are to be as required for cargo tanks, but the scantlings of cofferdam bulkheads where they are not cargo tank bulkheads are to comply with the requirements of D 5309 for plating and may have stiffeners as required by D 19.

Continuity of Strength

5524 Continuity of strength is to be maintained at the scarphing of longitudinal and transverse framing and in cofferdams.

The longitudinal deck framing is to extend one-third of the breadth of the ship into the poop. The side longitudinals are to extend abaft the poop front and the terminating positions of the longitudinal systems at sides and bottoms are to be staggered.

The longitudinal bulkheads are to extend well aft into the engine room and are to be suitably tapered at their ends.

Connections

5525 Web frames are to be suitably connected at top and bottom to members of adequate stiffness. Stringers are to be bracketed to the bulkheads. The stringer web and face plate are to be efficiently connected to the web frames.

Cross-references

5526 For structural details and connections, see D 57. For section moduli of webs, girders, frames, etc., in association with plating, see D 53.

Section 56

SUPERSTRUCTURES AND DECKHOUSES

Forecastles

5601 All tankers are to be fitted with forecastles or increased sheer in accordance with the requirements of D 1702.

Superstructure Scantlings

5602 The scantlings of superstructures are to be as required by D 17, except that the upper limit of E₁ in D 1701, is to be 6,06 (1·20 British) instead of 5,55 (1·10 British). See also D 4203 and D 4204.

Deckhouse Scantlings

5603 The scantlings of deckhouses other than exposed casings and houses protecting openings to pump rooms are to be as required by D 17.

Houses Protecting Openings to Pump Rooms

5604 Houses protecting openings to pump rooms are to have end and side plating and end stiffeners as required for superstructures, irrespective of house size. The remaining items are to be as required for deckhouses.

Exposed Machinery Casings

5605 Exposed machinery casings, including the case where one end, or side, of a machinery casing forms part of an end or side of a superstructure or deckhouse, are to have scantlings as required by D 1706 and D 1707.

5606 There is not to be direct access to the machinery space from the freeboard deck.

Doors may be fitted in exposed machinery casings provided they lead to a space or passageway which is of equivalent strength to the casing, and is separated from the machinery space by a second weathertight door, see 5608.

Doors and Entrances

5607 Openings in poop fronts are to have sills not less than 450 mm (17.5 in) high.

5608 Doors in houses over pump rooms and in exposed machinery casings are to be of steel and weather-tight. They are to be permanently attached by means of hinges and capable of being operated from both sides.

The door sills are to be not less than 600 mm (23.5 in) high if situated on the freeboard deck level, and not less than 380 mm (15 in) elsewhere.

General

5609 Where superstructures or deckhouses are of unusual design, additional strength may be required.

Section 57

STRUCTURAL DETAILS

Transverses, Webs, Stringers and Girders

5701 All primary supporting members, such as transverses and webs, stringers and girders, are to be so arranged that effective continuity of strength throughout their length is ensured and abrupt changes in depth or section at their connections are avoided; if the edges are flanged, the arrangement at the junction of the member and the bracket

is to be of careful design and execution. Primary supporting members are to have adequate end fixity, web stiffening and lateral support.

All longitudinals, stiffeners, etc., are to be attached to the primary supporting member as required by Table D 57.6.

Arrangements at Ends of Primary Supporting Members

5702 When face plates are carried continuously along the edges of end brackets of primary supporting members, their butts are to be kept clear of the toes of the brackets. The full width of the face plate is to be determined as far as the span point.

If not carried along the edge of the bracket the face plates of these members are to extend a reasonable distance beyond the toes of the brackets.

Where a wide face plate abuts on a narrower face plate, the taper is generally not to exceed 1 in 3, elsewhere the taper may be 1 in 2. Where a thick face plate abuts on a thinner face plate, if the difference in thickness exceeds 3 mm (0·125 in), the taper on the thickness is not to exceed 1 in 3.

5703 End brackets are to be stiffened as in Table D 57.1.

The bracket stiffener, when required, is to be parallel to the free edge and generally not more than a quarter of the throat depth from it. Large brackets may also require stiffening in line with the girder face plate.

The thickness of the end bracket is not to be less than the thicker of the webs being connected unless additional stiffeners are fitted when the thickness may be reduced by 1 mm (0.04 in), provided the compartment minimum is maintained.

TABLE D 57.1

Length of free edge		Bracket stiffening		
Above	Not exceeding	Flange or face plate	Additional flat stiffener	
mm	mm	mm	mm	
(in)	(in)	(in)	(in)	
-	1270 (50)	100 (4)	-	
1270	1650	125	-	
(50)	(65)	(5)		
1650	2030	125	100	
(65)	(80)	(5)	(4)	
2030	2540	150	100	
(80)	(100)	(6)	(4)	
2540 (100)	=	200 (8)	125 (5)	

5704 Brackets are to be well hollowed out or attached to a flat on the bulkhead plating. The flat is to extend to an adjacent stiffener or is to be well tapered off.

End brackets to horizontal girders on the transverse bulkheads are to be carried to the adjacent transverse and vertical web or equivalent arrangements provided.

5705 The angle between the free edge of the bracket and the face plate of the primary member is not to exceed 45°; if necessary, the edge of the bracket is to be curved at the toe.

5706 Special attention is to be paid to the tripping brackets of girders or webs on corrugated bulkbeads to avoid causing hard spots on the bulkhead. All brackets are to be well hollowed and are to be situated as close to the corner of the corrugation as practicable, or other suitable arrangements made to dissipate the load at the bracket toe.

5707 Where members abut on both sides of bulk-heads or on other members care is to be taken that they are in alignment.

Web Stiffening

5708 Stiffeners are to be fitted to web plates at each frame, longitudinal or bulkhead stiffener except that on deck transverses and on side transverses and vertical webs within 0,25D from the deck at side, the stiffeners need only be fitted at alternate longitudinals. Elsewhere the spacing of stiffeners is generally not to be more than 1050 mm (42 in).

Flat bar stiffeners are to have the depth given in Table D 57.2 and minimum compartment thickness. Other types of stiffeners are to be of equivalent inertia.

Where the depth of the web exceeds 1525 mm (60 in) the stiffening arrangements will be specially considered, taking into account the number of attached girders, etc., and any stiffeners arranged parallel to the face plate of the girder.

Long stiffeners are to extend to the face edge of the web. In way of end brackets, or where required by 5713, the stiffeners are to be attached to the face plate or equivalent arrangements provided.

Short stiffeners are to extend to half the depth of the web but at least beyond the lightening holes or 150 mm (6 in) beyond the notches.

The requirements of Table D 57.6 as regards area of weld are also to be complied with.

5709 Where bulkheads are horizontally corrugated and the vertical webs are arranged on one side of the bulkhead only, vertical stiffening of the web is to be provided when the depth of the web exceeds 1065 mm (42 in). The stiffener should be a 150×90 mm ($6\times3\cdot5$ in) toe welded angle of minimum compartment thickness or equivalent area.

TABLE D 57.2

Depth	of Girder	Stiffeners		
Above	Not exceeding		Stilleners	
mm	mm	mm		
(in)	(in)	(in)		
-	610 (24)	75 (3)	Short and long alternately	
610	915	100	Short and long alternately	
(24)	(36)	(4)		
915	1065	125	Short and long alternately	
(36)	(42)	(5)		
1065	1220	125	All long	
(42)	(48)	(5)		
1220	1525	150	All long	
(48)	(60)	(6)		

* All long in way of end brackets.

5710 Vertical webs on plane transverse bulkheads are to be stiffened in accordance with 5709 when the depth of web exceeds 1900 mm (76 in). Similar stiffening may be required on other vertical webs when the depth is excessive.

5711 Stiffeners of the size given in 5708 are generally to be fitted to the deck centreline girder and bottom and deck side girders not more than 1050 mm (42 in) apart. All stiffeners are to extend to the face plate. In deep centreline girders horizontal stiffening is to be arranged.

Lateral Stability

5712 Tripping brackets are to be fitted at suitable intervals. In general, they should be fitted near the toes of end brackets and in way of cross ties, while arrangements at the intersections of longitudinal and transverse webs, vertical and horizontal webs should be adequate to prevent tripping. Where the span is long, additional brackets are to be fitted as necessary.

5713 Where the unsupported width of face plate exceeds 150 mm (6 in) the tripping bracket is to be connected to the face plate. Where, with symmetrically placed face plates, the width of face plate exceeds 400 mm (16 in) a small bracket connected to the face plate is to be fitted opposite, and in line with, the tripping bracket. Wide face plates may require to be supported between tripping brackets.

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Notches

5714 All notches are to have well rounded corners and smooth edges and are not to be larger than necessary. When notches occur at points where stress concentration may develop, such as adjacent to the toes of brackets, a welded collar or equivalent reinforcement is to be fitted. Collars are also to be fitted in way of cross ties.

Lightening, Access, Drain and Air Holes and Holes for Heating Coils, etc.

5715 The diameter of lightening holes is not to exceed 20 per cent of the depth of the web; the edges of the holes should be placed at not less than 40 per cent of the depth of the web from the face and equidistant from the corners of notches for frames or stiffeners. Lightening holes are not to be cut in horizontal girders on the ship's side and longitudinal bulkheads, in symmetrical webs nor in side transverses and vertical webs in way of cross ties and their end connections. Access holes or foot holes may be cut in deep bottom transverses and centre girders with suitable compensation if necessary. All holes are to have smooth edges and are to be kept well clear of notches and the toes of brackets.

5716 Small drain or air holes may be cut in deep framing members and in longitudinals and stiffeners. These holes should be kept clear of the toes of end brackets and are to be well rounded with smooth edges. See also D 4107.

5717 Where holes are cut in the bottom transverses for heating coils the lower edge of the hole is to be not less than 100 mm (4 in) from the inside of the shell plating.

5718 The edges of all holes in transverses are to be at least 180 mm (7 in) from the edges of notches for longitudinals.

Welded Connections

5719 The requirements for welded connections and details of scalloped construction are given in Tables D 57.3, D 57.4, D 57.5 and D 57.6. All scallops are to have well rounded corners and smooth edges. (For general particulars see Table D 57.3.) Scallops are not to be cut in way of end brackets, and scallops in the stiffening members are to be at least 230 mm (9 in) clear of the toe of the bracket. Scallops in longitudinals, side frames and stiffeners are also to be omitted for at least 230 mm (9 in) on each side of intersection with a primary supporting member. Scallops are not to be cut in bottom transverses or in horizontal girders on ship's side or longitudinal bulkheads, and in ships over 122 m (400 ft) in length, scallops are not to be cut in the lower half of side transverses or vertical webs on longitudinal and transverse bulkheads.

TABLE D 57.3 (see continuation)

WELDING OF VARIOUS STRUCTURAL CONNECTIONS

	ITEM	WELD FACTOR
	FRAMES & LONGITUDINALS	
	in cargo tanks, spacing not over 760 mm (30 in)	0,11 (0·16)
	in cargo tanks, spacing over 760 mm (30 in)	0,12 (0·17)
	in deep, oil fuel and peak tanks	0,12 (0·17)
	in fore hold	0,12 (0·17)
Side frames	in machinery space, spacing not over 740 mm (29 in)	0,09 (0·13)
to shell	in machinery space, spacing over 740 mm (29 in) a up to 810 mm (32 in)	nd 0,10 (0·14)
	in machinery space, spacing over 810 mm (32 in) a up to 860 mm (34 in)	nd 0,11 (0·16)
	in machinery space, spacing over 860 mm (34 in)	0,12 (0·17)
Tween deck fra	mes and longitudinals to shell	0,09 (0·13)
Web frames	*** *** *** *** *** *** ***	See Table D 57.4
Bottom	for a distance either side of the bulkhead equal to 0,30 spacing of transverses	× 0,35 (0·50) 0,11 (0·16) when longitudinals continuou at bulkhead
to shell	remainder (except in the forward 0,25 L)	0,11 (0.16)
(except as below)	in the forward 0,25 L (except at ends of span, where above)	88 0,22 (0·32)
Bottom longitu	dinals of flat bar type to shell	Continuous weld 0,25 (0·35) but need no exceed 5,5 mm (0·30 in) hand or 4,5 mm (0·25 in) automatic (see also Note 1—Table D 57.3)
	not over 4,6 m (15 ft) below upper deck at side am ships	0,11 (0·16)
C:4.	over 4,6 m (15 ft) for a distance either side of but head equal to 0,25 × spacing transverses	
Side longitudinals	ships remainder	0,11 (0·16)
to shell	over 7,6 m (25 ft) below upper deck at side amidships for a distance either side of but head equal to 0,25 × spacing transverses	
	- Vaccinated as	0,11 (0.16)

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TABLE D 57.3 (see continuation)

WELDING OF VARIOUS STRUCTURAL CONNECTIONS

ITEM	WELD FACTOR
Deck longitudinals of flat bar type to deck plating	Continuous weld—0,25 (0·35) but need no exceed 5,5 mm (0·30 in) hand or 4,5 mm (0·25 in) automatic (see also Note 1
Longitudinals to stiffening bars on primary supporting members	See Table D 57.6
Intercostal bottom side girders to shell	As for bottom longitudinals
Intercostal deck side girders to deck plating	As for deck longitudinals
Face bar of intercostal bottom and deck side girders to respective web plates	0,13 (0·19)
Bottom frames to shell and floors forward	0,22 (0.32)
Floors to centre girder or centreline bulkhead forward	0,44 (0.63)
Floors and cross ties in fore peak	0,11 (0.16)
Floors and cross ties in after peak	0,13 (0·19)
Web frames to shell	See Table D 57.4
Bottom transverses to longitudinal bulkheads and centreline girder	0,44 (0.63)
Deck transverses to longitudinal bulkheads and centreline girder	0,35 (0.50)
BRACKETS	hele presign and and in element part and hele
End brackets of all primary supporting members	0,44 (0.63)
Brackets at head of side frames	See Table D 57.5
Side frames to bilge brackets	To depend on arrangements adopted
End connections of longitudinals	Generally 0,44 (0.63) but to depend on design
Brackets at ends of stiffeners on transverse bulkheads	To depend on end connections of longitudina
Tripping brackets	0,11 (0.16)
Docking brackets	0,13 (0·19)
Stiffening of primary supporting members. See also Table D 57.6	0,09 (0.13)

TABLE D 57.3 (concluded)

WELDING OF VARIOUS STRUCTURAL CONNECTIONS

		WELD FACTOR		
0.T. T	RANSVERSE & L	ONGITUDINAI	BULKHEADS	
Vertical stiffeners	spacing not exc	eeding 760 mm	(30 in)	0,11 (0·16)
suneners	spacing exceedi	ng 760 mm (30	in)	0,12 (0·17)
	not over 4,6 m	(15 ft) below hig	ghest point of tank	0,11 (0·16)
Horizontal bulkheads stiffeners	over 4,6 m (15 ft) and not over 7,6 m (25 ft)	for a distance either side of bulkhead equal to $0.25 \times \text{spacing of transverses}$	0,35 (0.50) 0,11 (0.16) when longitudinals continuou at bulkhead	
		(25 16)	remainder	0,11 (0·16)
		over 7,6 m (25 ft)	for a distance either side of bulkhead equal to 0,25×spacing of trans- verses	0,35 (0.50) 0,11 (0.16) when longitudinals continuous at bulkhead
		remainder	0,11 (0.16)	
	on transverse bulkheads	not over 5,5 m of tank	(18 ft) below highest point	0,11 (0·16)
buiknesus		over 5,5 m (18	ft)	0,13 (0·19)
	of longitudinal	bulkheads to b	ottom or deck	0,44 (0.63) (continuous) See note 5
Boundaries <		to shell at bot	tom or bilge	0,44 (0.63) (continuous)
	of transverse bulkheads	to shell at sides or to deck		0,35 (0·50) (continuous)
		to longitudinal bulkheads		0,35 (0·50) (continuous)
Vertical webs		222		See Table D 57.4

NOTES.—TABLE D 57.3

1. Thickness to be used in determining throat thickness (leg length) is generally to be that of the thinner of the two

parts being joined.

Where slab type longitudinals are fitted to the bottom shell, upper deck, or longitudinal oiltight bulkheads in the upper or bottom 0,1D, within 0,4L amidships, the thickness used to determine the throat thickness (leg length) is not to be taken as less than half the thickness of the longitudinal.

Where the difference between the thicknesses of the parts to be joined is considerable the size of fillet will be

specially considered.

2. Throat thickness (leg length) for double continuous fillets is to be the product of the plate thickness and the

weld factor given in Table D 57.3.

Within the cargo tanks double continuous fillets having a throat thickness (leg length) of less than 0.35 (0·50) of the plate thickness are to be restricted to longitudinal framing and to bulkhead stiffening.

Where automatic deep penetration welds are used the values derived as above may be reduced by 15 per cent.

In no case (except for slab longitudinals) is the throat thickness (leg length) to be less than $0.21 \times \text{plate}$ thickness ($0.30 \times \text{plate}$ thickness) nor is it to be less than 3,5 mm (0.18 in) for hand and automatic welding or 3 mm (0.16 in) for automatic deep penetration welding.

For hand welded fillet welds on internal bulkheads not exceeding 6 mm (0.24 in) in thickness a minimum throat thickness (leg length) of 3 mm (0.16 in) is acceptable.

3. Throat thickness (leg length) for intermittent fillets is to be given by the formula:—

Throat thickness (leg length) =

plate thickness \times weld factor $\times \frac{d}{s}$

where d and s are defined in Fig. 57.1.

The length s should not be less than 75 mm (3 in) and the ratio of s and d is to be such that the required throat

thickness (leg length) does not exceed $0.49 \times \text{plate}$ thickness ($0.70 \times \text{plate}$ thickness) or 4.5 mm (0.24 in) whichever be the greater.

In no case, however, is the throat thickness (leg length) of intermittent fillet welds to be less than $0.28 \times \text{plate}$ thickness ($0.40 \times \text{plate}$ thickness) or 3,5 mm (0.18 in) whichever be the greater.

4. Leg length of welds is to be not less than 140 per cent of the throat thickness derived as above or as required by Table D 57.5, Note 2.

or in British units:-

- 4. Throat thickness of welds is to be not less than 70 per cent of the leg length derived as above or as required by Table D 57.5, Note 2.
- 5. Where the top and bottom strakes of the longitudinal bulkhead are increased in thickness above the requirements of D 5007, the welding to deck or bottom shell is not to be less than that based on the thickness required by D 5007 or a throat thickness (leg length) 25 (35) per cent of the actual plating thickness, whichever is the greater.
- Fillet welds in after peak tanks or on after peak bulkhead stiffeners are to be continuous. It is recommended that all fillet welds in all tanks be continuous.

Where the thickness of bottom or deck longitudinals exceeds the thickness of the shell or deck plating the welding is to be continuous.

- 7. Welding at the ends of bulkhead stiffeners etc., (whether associated with brackets or lugs) is to give, when not otherwise specified in Tables D 57.3, D 57.4, D 57.5 and D 57.6, a weld area (length of weld×throat thickness) of 25 per cent of the cross-sectional area of the stiffener with a minimum of 6,5 cm² (1 in²).
- The welding of girders, webs, beams and frames to shell and deck in way of end brackets or knees that require continuous welds, should also be continuous.

STAGGERED INTERMITTENT

To be doubled at ends. See D 3210

CHAIN INTERMITTENT

SCALLOPED FRAMES, LONGITUDINALS, STIFFENERS, etc., WITH DOUBLE FILLET WELDS

Welding to be carried round the ends of all lugs See also D 5719

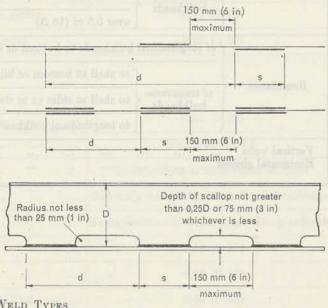


Fig. D 57.1 Weld Types

TABLE D 57.4

CONNECTION OF PRIMARY SUPPORTING MEMBERS TO FACE MATERIAL, SHELL, DECK AND BULKHEAD

		AND THANKSHOOD BULKHEADS		WEI	LDED
FACE AREA		POSITION	TO FACE MATERIAL	TO SHELL, DECE OR BULKHEAD	
		ne ad put ad afot sa su units an a		WELD FACTOR	WELD FACTOR
Above	Not exceeding 30,0	For a distance each end equal to 0,2×length		0,15 (0.21)	0,30 (0.42)
	(5.0)	Remainder	***	0,10 (0·14)	0,15 (0.21)
30,0 (5·0)	65,0 (10·0)	For a distance each end equal to 0,2×length		0,22 (0.31)	0,35 (0.50)
(0 0)		Remainder	•••	0,12 (0.16)	0,27 (0.38)
65,0 (10·0)	95,0 (15·0)	For a distance each end equal to $0.2 \times length$.,,	0,35 (0.50)	0,44 (0.63)
(10 0)	(10-0)	Remainder		0,35* (0.50)*	0,35 (0.50)
95,0 (15·0)	130,0 (20·0)	For a distance each end equal to 0,2×length	***	0,35 (0.50)	0,44 (0.63)
(10.0)	(20.0)	Remainder		0,35* (0.50)*	0,35 (0.50)
130,0	260,0	For a distance each end equal to 0,2×length		0,44 (0.63)	0,44 (0.63)
(20.0)	(40.0)	Remainder	***	0,35 (0.50)	0,35 (0.50)

* May be 0,28 (0.40) clear of oil cargo tanks

NOTES.-TABLE D 57.4

- Length for use in the above Table is the unsupported length of the member including end connections.
- 2. The extent of the increased connection at each end equal to 0,2×length given in the above Table is measured from the end of the member including the end bracket, but this length is to be extended as necessary beyond the toe of the bracket, and beyond the heel of the bracket to cover a contiguous member.
- 3. On vertical webs the increased welding may be omitted at the top, but at the bottom it is to extend for a distance equal to 0,3×length,
- 4. In ships over 122 m (400 ft) long the weld factor of the connection of bottom transverses to the shell is not to be less than 0,35 (0.50) and that of the side transverses to shell, and the vertical webs to longitudinal and transverse bulkheads is not to be less than 0,35 (0.50) in the lower half.
- 5. Centreline deck and bottom girders are to be welded as given in the above Table.
- For particulars of scalloped construction, see D 5719 and Notes to Table D 57.3.

TABLE D 57.5

BRACKETS AT HEAD OF SIDE FRAMES AND AT ENDS OF VERTICAL STIFFENERS TO LONGITUDINAL

AND TRANSVERSE BULKHEADS

1. The dimensions of brackets and their connections are not to be less than those given by the following formulæ:-

Length of Arm (
$$l$$
) = 28,3 $\sqrt{\frac{1}{y}}$ + 50 mm
(Length of Arm (l) = 4.5 $\sqrt{\frac{1}{y}}$ + 2 in)

Thickness =
$$0.184\sqrt{\frac{1}{V}}$$
 + 6.5 mm, or 9 mm, whichever is the greater but need not exceed 12.5 mm

(Thickness =
$$0.03\sqrt{\frac{I}{y}} + 0.25$$
 in, or 0.36 in, whichever is the greater but need not exceed 0.50 in)

Flange Width
$$= 3.14 \sqrt{\frac{I}{y}} + 12.5 \text{ mm}$$
, or 100 mm, whichever is less (see 4 below)

(Flange Width
$$0.5\sqrt{\frac{1}{y}} + 0.50$$
 in, or 4 in, whichever is less)

Weld Area =
$$0.042 l \text{ cm}^2 \text{ if } l \leq 610 \text{ mm}$$

(see 2 below)

(Weld Area
$$= \frac{l}{6} \text{ in}^2 \text{ if } l \leq 24 \text{ in}$$
)

Weld Area =
$$0.064 l - 13 \text{ cm}^2 \text{ if } l > 610 \text{ mm}$$
 (see 2 below)

(Weld Area
$$= \frac{l}{4} - 2 \text{ in}^2 \text{ if } l > 24 \text{ in}$$
)

Where
$$\frac{I}{y}$$
 = Section modulus of frame or stiffener in cm³ (in³).

- 2. Area of weld is the product of the throat thickness and the total length of weld, but the throat thickness is not to be less than 0,35 of the plate thickness, or 3 mm (0·12 in), whichever be the greater. See Table D 57,3.
 - 3. Length of bracket arm is to be measured from the plating.
 - 4. Flanges need not be fitted where the length of bracket arm is less than 460 mm (18 in).
 - 5. For minimum thickness, see D 5309.

TABLE D 57.6

CONNECTIONS OF LONGITUDINALS, FRAMES AND STIFFENERS TO PRIMARY SUPPORTING MEMBERS

1. The weld area connecting longitudinals, frames and stiffeners to primary supporting members is not to be less than the greater of the values given by the following formulæ:—

Bottom Transverses
$$A = 0.88$$
 $\sqrt{\frac{I}{y}}$ or $0.0612 \frac{1}{S} \frac{I}{y}$ cm²
$$(A = 0.55 \sqrt{\frac{I}{y}} \text{ or } 0.51 \frac{1}{S} \frac{I}{y} \text{ in}^2)$$
Deck Transverses $A = 0.44 \sqrt{\frac{I}{y}}$ or $0.0306 \frac{1}{S} \frac{I}{y} \text{ cm}^2$
$$(A = 0.275 \sqrt{\frac{I}{y}} \text{ or } 0.255 \frac{1}{S} \frac{I}{y} \text{ in}^2)$$
Side Transverses and bulkhead webs and girders
$$A = 0.88 \sqrt{\frac{I}{y}} \text{ or } 0.109 \frac{1}{S} \frac{I}{y} \text{ cm}^2$$

$$(A = 0.55 \sqrt{\frac{I}{y}} \text{ or } 0.908 \frac{1}{S} \frac{I}{y} \text{ in}^2)$$

In no case is the area to be less than 13 cm² (2 in²)

where A = area of weld in cm² (in²) as defined in 2 below.

 $\frac{I}{V}$ = section modulus of longitudinal, frame or stiffener in cm³ (in³).

S = span of longitudinal, frame or stiffener in metres (feet).

- 2. Area of weld is the product of the throat thickness and total length of weld and includes both weld of web connection and weld of connection to stiffening bar. The throat thickness is not to be less than 0,35 of the plate thickness, or 3 mm (0·12 in) whichever be the greater. See Table D 57.3.
- 3. Outside the tank space the area of weld may be 80 per cent of the value required by the formula and associated notes. The throat thickness of weld is not to be less than 0,30 of the plate thickness or 3 mm (0·12 in) whichever be the greater.

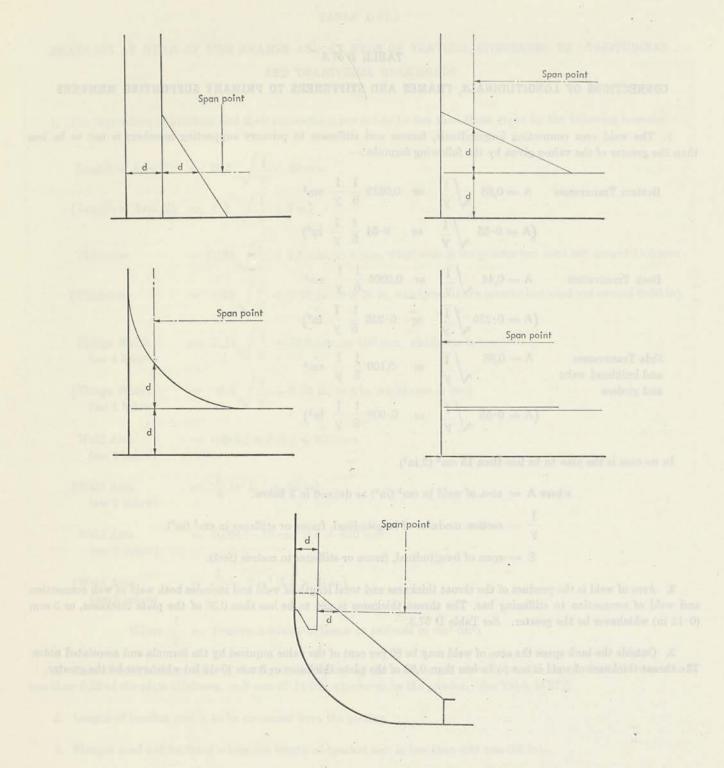


Fig. D 57.2 Span Point for Longitudinals, Frames and Stiffeners

APPLICATION OF HIGHER TENSILE STEEL

Section 65

GENERAL

Symbols

6501 D = moulded depth, in metres (feet),

L = length of ship, in metres (feet),

y = distance from the neutral axis to the deck or bottom of the ship, in metres (feet),

Y = specified minimum yield stress or 0,5 per cent proof stress, in kg/mm² (ton/in²),

 $\mathsf{F} = \frac{\text{Rule midship section modulus}}{\text{actual midship section modulus}}$

6502 Where higher tensile steel is extensively used in the main hull structure, a suitable descriptive notation will be inserted in the Register Book.

6503 To facilitate ordering of material for repairs, it is recommended that a plan should be placed on board indicating the location and extent of the higher tensile steel, together with details of the specification, including mechanical properties, of the steel.

Method of Construction

6504 The following requirements are applicable to ships where the bottom and deck are framed longitudinally. Proposals for ships with transverse framing of bottom or deck will be specially considered.

Material

6505 The higher tensile steel to be used is to comply with the requirements of P 3.

6506 For scantling purposes, a factor k shall be derived for the steel as follows:—

$$k = \frac{25}{Y} \quad \left(k = \frac{15 \cdot 8}{Y} \text{ British}\right)$$
or $k = 0.725 \quad (k = 0.725)$

whichever is the greater.

Special consideration will be given to steels where Y is greater than $36 \text{ kg/mm}^2 (22.8 \text{ ton/in}^2)$.

Longitudinal Strength

6507 The required section moduli at deck and keel, as determined from D 3 or D 41, are to be multiplied by the factor k or by 0,059 $\frac{L}{D}$, whichever is the greater.

6508 Where both higher tensile steel and ordinary mild steel are used for continuous longitudinal members, the whole of the topsides and the bottom is to be of higher tensile steel to a distance from deck and bottom at least equal to (1-k) y or $\left(1-0.059\frac{L}{D}\right)$ y, whichever is the lesser.

6509 Where higher tensile steel is proposed for the topsides only, the deck modulus may be reduced as given in 6507 and 6508, except that the following value should be used instead of 0,059 $\frac{L}{D}$:—

$$\frac{0,059 \frac{L}{D}}{1 + f \left(1 - 0,059 \frac{L}{D}\right)}$$

where f = 1,0 for cargo ships, 0,97 for oil tankers up to 100 m (328 ft) in length, 1,0 for oil tankers of 300 m (984 ft) and above, with intermediate values by interpolation.

Structural Members

6510 The requirements of the following paragraphs should be applied to the scantlings of the structural members as determined from the appropriate Section of the Rules.

Special attention should be paid to detail design having regard to cyclic loading.

Shell Plating

6511 The thickness of side shell is to be reduced by the factor \sqrt{k} . The minimum thickness of the bottom shell plating may be reduced by the factor \sqrt{k} subject to compliance with longitudinal strength requirements.

The thickness of bilge plating where longitudinally framed is not to be less than:—

- (a) that determined from D 504 or D 4304 with no correction for higher tensile steel,
- (b) that determined from D 504(a) or D 4302, using the actual spacing of bilge longitudinals and corrected as given above for bottom shell, whichever is the lesser.

Deck Plating

6512 The thickness of deck plating is to be determined by longitudinal strength requirements, and the minimum thickness may be reduced by the factor \sqrt{k} .

Longitudinal Framing

6513 The section modulus of deck, side, bottom and inner bottom longitudinals is to be multiplied by the factor k.

The spacing of deck and bottom longitudinals for 0.4L amidships, in mm (in), is not to be greater than $55t\sqrt{\frac{k}{F}}$ but in no case is to exceed $65t\sqrt{k}$, where t is the thickness of the deck plating or bottom shell, as appropriate, in mm (in).

The minimum breadth of face bar is to be 15 per cent greater than given by D 4404.

The maximum web depth to web thickness ratios given in D 4404 are to be multiplied by the factor \sqrt{k} .

Girders

6514 The section modulus of deck and bottom girders is to be multiplied by the factor k, and the spacing of longitudinal stiffeners on the web is not to be greater than $55t\sqrt{\frac{k}{F}}$, but in no case is to exceed $65t\sqrt{k}$, for 0,4L amidships.

Double Bottom

6515 The height of the double bottom is to be as required by the appropriate Section of the Rules, but the thickness of floors, girders and tank top are to be multiplied by the factor \sqrt{k} . The factor should be applied to the Rule thickness of tank top plating and the full increase for grab discharge (if applicable) added to this corrected thickness

15th July, 1971

Bulkheads

6516 The section modulus of the stiffeners is to be multiplied by the factor k and the plating thickness by the factor \sqrt{k} . Corrugated bulkheads may be similarly treated except that the minimum moment of inertia shall not be reduced.

Cross Ties

6517 The area of cross ties is to be multiplied by the factor k. The least moment of inertia shall not be reduced.

Minimum Thickness

6518 The minimum thickness of structural items may, in general, be reduced by the factor \sqrt{k} , but where items other than those referred to in 6511 to 6517 are subjected to compressive loading their scantlings will be specially considered, account being taken of panel stability.

Grades of Steel

6519 Where higher tensile steel replaces Grades A, B and D mild steel for parts of the structures, then Grade AH may be used for plates up to and including a thickness of 25,5 mm (1·0 in) and Grade DH quality is to be used whenever the thickness of the higher tensile plates exceeds 25,5 mm (1·0 in), except that slab type longitudinals flame cut from plate may be of Grade AH up to a thickness of 35,5 mm (1·4 in) provided that the carbon equivalent of the steel does not exceed 0,41 per cent. Where the carbon equivalent is greater than 0,41 per cent, then Grade DH steel is to be used for these items if their thickness exceeds 20,5 mm (0·8 in).

Grade EH plates are normally to be substituted for Grade E (but see also D 411).

For formula for carbon equivalent, see P 302.

REQUIREMENTS FOR THE CARRIAGE OF LIQUEFIED GASES

(The attention of Builders and Owners is directed to the fact that compliance with these Rules may involve the obtaining of licences under existing patents.)

Section 70

GENERAL

Class

7001 The class 100Al Liquefied Gas Carrier, type of gas(es) in independent tanks, maximum vapour pressure, minimum temperature and, where necessary, maximum temperature (to be specified), will be assigned to ships specially designed for the carriage of liquefied petroleum natural or other gases in separate tanks and built in accordance with, or equivalent to, the relevant sections of the Rules and the requirements in this section in conjunction with D 71 or D 72 as appropriate.

These requirements are primarily intended to apply to ships having machinery aft and built for the carriage of liquefied petroleum or natural gases in separate tanks and special consideration will be given to the requirements necessary for other liquefied gases. Arrangements incorporating integral or membrane tanks will also be specially considered.

Longitudinal Strength

7002 The required section modulus at deck and keel is to be determined in accordance with D 3 of the Rules as required therein for the class 100A1.

Extent of Midship Scantlings

7003 The midship scantlings are to be maintained for 0,4L amidships.

Grades of Steel

7004 Where the seams and butts are welded, steel of Grades B and D (see Table P 2.2) will generally be required for the parts of the structure as shown in Table D 70.1.

7005 Strakes of Grade E steel are to be arranged as required by D 513.

7006 For scantlings and arrangements if higher tensile steel is used, see D 65.

Double Bottom Structure

7007 The scantlings of the double bottom structure are to be determined in accordance with D 9. Where wing ballast tanks or floodable cofferdams are common with the double bottom tanks, the scantlings of the tank top must also satisfy D 19.

Bottom Shell

7008 The thickness of the bottom shell amidships to upper turn of bilge is to be that necessary to give the required section modulus but is not to be less than required by D 5.

Side Shell

7009 The thickness of the side shell plating is to be determined from D 5.

Transverse Side Framing

7010 The scantlings of transverse side frames are to be obtained from D 7. Where an inner hull is provided and the side frames are supported by stringers the required section modulus of the frames is to be in accordance with the requirements of D 719 to D 722.

Longitudinal Side Framing

7011 The section modulus of side longitudinals is to be not less than:—

$$\frac{1}{y} = \frac{\text{s S}^2}{118} \Big\{ h + \frac{2,5d - D}{6} \Big\} \text{cm}^3$$

$$\left(\frac{1}{y} = \frac{\text{s S}^2}{2680} \left\{ h + \frac{2 \cdot 5d - D}{6} \right\} in^3 \right)$$

where S = spacing of longitudinals, in mm (in),

S = span, in metres (feet), measured between transverses or from transverse to "span point",

h = distance of longitudinal below deck at side, in metres (feet),

d = summer draught measured from top of keel, but not less than 0,4D, in metres (feet).

TABLE D 70.1

	GRADES O	F PLATING	REMODIREMENTS FOR THE
ITEM	Thickness greater than 20,5 mm (0·8 in) but not exceeding 25,5 mm (1·0 in)	Thickness greater than 25,5 mm (1 · 0 in)	EXTENT
TOPSIDE STRUCTURE Amidships Sheer strake Strength deck stringer Top strake longitudinal bulkheads Longitudinals of slab type cut from plates on:— (i) Deck (ii) Side shell and longitudinal bulkheads for 0,1D from deck Through brackets for deck longitudinals on side shell and longitudinals on side shell and longitudinal bulkheads for 0,1D from deck	В	D	0,4L amidships—forward limit must extend at least 3 m (10 ft) forward of the bridge front when a midship bridge is fitted
Clear of Amidships Sheerstrake Strength deck stringer Strength deck plating Poop front	В	D.	
Sheerstrake Outside the Strength deck stringer above limits		D	teninal estimates and missipalitation for uncalcular tenings.
BOTTOM STRUCTURE Bottom shell to upper turn of bilge* Bottom strake of longitudinal bulkheads Longitudinals of slab type cut from plates on:— (i) Bottom shell (ii) Side shell and longitudinal bulkheads for 0,1D from bottom Through brackets for bottom longitudinals and also for longitudinals on side shell and longitudinal bulkheads for 0,1D from bottom * Keel plate is to be same Grade as adjacent	B	D	When L = 155 m (508 ft) and below for 0,3L amidships When L = 215 m (705 ft) and above for 0,4L amidships Intermediate values by interpolation

7012 Side transverses are to be spaced not more than 3,66 m (12 ft) apart and the section modulus is to be not less than:-

$$\frac{\mathrm{I}}{y} = \frac{\mathrm{s} \; h \; \mathrm{S}^2}{k} \; \mathrm{cm}^3 \quad (\mathrm{in}^3)$$

where s = spacing of transverses, in metres (feet),

S = span of transverses, in metres (feet),

h = head from midpoint of span to deck at side, in metres (feet),

 $k = 81.6 \times 10^{-3}$ (155 British) when d/D = 0.75and above, 94.8×10^{-3} (180 British) when d/D = 0.50

with intermediate values by interpolation. The requirements of D 4608 and D 4609 are to be complied with.

Inner Hull

7013 Where an inner hull is fitted to form wing ballast tanks (see D 7102) the scantlings are to be as required by D 19.

7014 The width of the wing tank and the spacing of the side transverses are to be such that the transverses, in association with the effective area of shell and bulkhead plating (see D 5304), have a section modulus not less than that given by 7012.

Decks

7015 The thickness of deck plating is to be determined from the requirements of 7002 but is to be not less than the minimum thickness as determined from D 403.

7016 The scantlings of beams or longitudinals are to be obtained from D 8 and D 6.

7017 The section modulus of deck transverses is to be as required by D 13.

Transverse Bulkheads

7018 The scantlings of single transverse watertight bulkheads are to be determined from D 18.

7019 Where the transverse bulkheads are arranged as floodable cofferdams (see D 7103) the scantlings of the bulkheads are to be in accordance with D 19.

Cross-references

7020 For filling, discharging and venting pipe arrangements, see E 12.

For electrical installations, see M 16.

For refrigerating machinery and arrangements, see E 12.

For the use of methane gas as fuel for propulsion purposes, see Chapter R (A).

Section 71

CARRIAGE AT A PRESSURE OF 0,70 kg/cm² (10 lb/in²) GAUGE OR LESS

Submission of Plans

7101 In addition to those required by D 109 the following plans are to be submitted:—

Scantlings of cargo tanks.

Details of tank supports and keying arrangements.

Fire extinguishing arrangements.

The following should also be submitted:-

Calculations for dynamic loading of cargo tanks (see 7116).

Specification for tank material including results of low temperature tests.

Ship's Structure

7102 Vessels are to have a double bottom and, where the cargo is to be carried at a temperature below -10°C (+14°F), are generally to be provided with two longitudinal bulkheads forming side tanks.

7103 Cofferdams are to be arranged at each end of the tank space. Other transverse bulkheads are to be arranged as floodable cofferdams when the minimum cargo temperature is below -50°C (-58°F).

7104 When the minimum cargo temperature is below -10°C (+14°F) a secondary barrier is to be provided which will act as a temporary containment for the liquefied gas in the event of a leakage from the containers.

Provided the minimum cargo temperature is not below -50° C (-58° F), this containment may be provided by the hull structure, but with this arrangement the grades of steel in the containing hull structure are to be dependent (subject also to the requirements of D 7004 and D 7005) on the minimum steel temperatures which may arise in the event of leakage from the cargo tanks, as follows:—

7105 The insulation arrangements are to be such that the minimum steel temperature in the hull structure adjacent to the cargo tanks does not fall below the following values when the cargo tanks are at the minimum service temperature and the air temperature is 5°C (41°F) and the water temperature is 0°C (32°F):—

Grade A ... 0°C (32°F)

Grade D... −5°C (23°F) for strength deck and longitudinal stuctural members attached to strength deck within 0,5L amidship.

Grade D ... -10°C (14°F) elsewhere

Grade E ... −20°C (−4°F)

The temperatures of the hull structure should not normally be allowed to fall below -20°C (-4°F).

7106 Where a secondary barrier separate from the hull structure is provided the following requirements are to be met:—

(a) The minimum hull steel temperatures, in the event of leakage from the cargo tanks, shall be not less than those given in 7104 for the particular grade of steel.

- (b) Thermo-couples are to be arranged on the ship's structure adjacent to the cargo tanks and the arrangements are to be such as to give continuous temperature readings and audible warning of the development of temperatures lower than given in 7104. In general, such thermo-couples are to be arranged not more than 6,1 m (20 ft) apart.
- (c) The extent of the secondary barrier is to be such that the liquefied gas will not come into contact with the hull structure in the event of failure of one cargo tank with the ship heeled to an angle of 30°.
- (d) The secondary barrier shall be capable of containing the liquefied gas for a period of at least 14 days.
- 7107 Arrangements are to be provided to enable the double bottom, wing tank spaces and all transverse cofferdams (where fitted) to be flooded in the event of leakage from the cargo tanks.
- 7108 Suitable arrangements are to be made for sealing the weather deck in way of openings for the cargo tanks.
- 7109 Any means of access to the spaces around the cargo tanks is to be from above the weather deck.
- 7110 The spaces containing the cargo tanks are to be permanently filled with an inert gas and a monitoring system is to be installed to ensure that any leakage from the tank is immediately detected.
- 7111 Arrangements are to be provided to prevent excessive pressure coming on to the containment spaces either during service or in the event of leakage from the cargo tanks.

Cargo Tanks

- 7112 The material to be used in the construction of the cargo tanks must have suitable mechanical properties at the service temperature. Particulars of the material proposed are to be submitted for approval.
- 7113 Where a ferritic steel is to be used, tensile, bend and Charpy V-notch impact test pieces are to be prepared from each plate or section. The dimensions of the test pieces are to be in accordance with the requirements contained in P 203, P 204, P 206 and P 207.

The results of the tensile and bend tests are to comply with the approved specification. For the Charpy V-notch impact tests the "required temperature" is the lowest service temperature and the results of the tests are to give an average energy for fracture of not less than 5,53 kg m (40 ft lb).

Other criteria and methods of testing will be accepted where considered equivalent to the above requirements.

- 7114 It is to be demonstrated by procedure tests that the proposed methods of welding are satisfactory and produce sound welds. Charpy V-notch impact test pieces are to be prepared from butt welded test plates and are to be notched in the heat-affected zone and, if the deposited metal is a ferritic steel, further test pieces are to be notched in the weld. Unless otherwise approved, the results of the impact tests on these test pieces at the minimum temperature of service are to be not less than those specified for the parent material.
- 7115 For materials other than ferritic steels, the proposed material specification is to be submitted. The notched properties as determined by suitable tests and/or evidence of comparable service experience, at temperatures lower than or equal to the minimum service temperature are also to be submitted, together with corresponding data on the weld metal and heat-affected zone.
 - 7116 The tanks shall be designed to withstand:-
 - (i) A test head of 2,44 m (8 ft) of water above the top of the tank or 0,61 m (2 ft) above the top of the hatch, whichever may be the greater.
 - (ii) The combined effect of internal vapour pressure (if any) and rolling, pitching and heaving as follows:—
 - A complete 30° roll port and starboard (i.e., through 120°) in a period of ten seconds.
 - (2) A pitch of 6° half amplitude in a pitch period of seven seconds (i.e., through 24° in seven seconds).
 - (3) A heave of 0,0125 L half amplitude in a period of eight seconds (i.e., through 0,05 L in eight seconds).

With the loading determined in accordance with the above, the stress in any item shall not exceed three-quarters of the yield stress or three-eighths of the ultimate stress.

- 7117 Means are to be provided to prevent excessive pressure coming on to the tanks (see E 12).
- 7118 The tanks are to be supported on substantial foundations arranged to avoid excessive concentration of load on the ship's structure or on the tank. Provision is to be made for the thermal contraction of the tanks on cooling

from ambient to service temperature and arrangements are to be made to control the movement of the tanks when the vessel is rolling and pitching.

7119 The arrangement of tanks and insulation is to be such that at least one side of the tank plating and adjacent hull structure is readily accessible for inspection.

7120 During the construction of the tanks all butt welds are to be radiographed.

7121 The tanks are to be tested on completion with a head of water in accordance with 7116 (i).

7122 Thermo-couples are to be fitted to at least one tank to enable a satisfactory pre-cooling procedure to be established unless other satisfactory arrangements can be made.

Insulation

7123 The insulation is to be of an approved type and of sufficient thickness to comply with 7105 of these requirements. It is to be suitable for the loads imposed and adequately protected against penetration of water vapour from the atmosphere.

Particulars of the insulating material(s) and the estimated heat conductivity value(s) at the service conditions are to be supplied, together with the proposed thickness(es) and methods of fitting, jointing and sealing the insulation.

Section 72

CARRIAGE AT A PRESSURE ABOVE 0,70 kg/cm² (10 lb/in²) GAUGE (WITH OR WITHOUT REFRIGERATION PLANT)

Submission of Plans

7201 In addition to those required by D 109 the following plans are to be submitted:—

Cargo Tank Seatings and Securing Arrangements.

Hold Ventilation System.

Fire Extinguishing Arrangements.

Ship's Structure

7202 Where the cargo is to be carried at a temperature below ambient, the requirements of D 7104 and D 7105 are to be complied with.

7203 Cofferdams, or single bulkheads of all-welded construction forming an "A" class fire-resisting division, are

to be arranged between spaces containing the cargo tanks and machinery spaces.

Installation of Cargo Tanks

7204 Cargo tanks are to be sited so that the following minimum clearances are obtained:—

- (a) Tanks to the side shell—generally 610 mm (24 in), but clearances at the ends of the ship below the load waterline will be specially considered.
- (b) Tanks to inner bottom plating-150 mm (6 in).
- (c) Tanks to bottom shell (if no inner bottom is fitted)—not less than the depth of centre girder given by D 904.

Where more than one tank is fitted in a space, sufficient clearance is to be left between tanks for inspection or repairs and in no case less than 300 mm (12 in).

7205 Cargo tank seatings and securing arrangements are to be suitable for dynamic loading to the extent given in D 7116 and should also be suitable for the forces arising when a cargo hold is flooded with the cargo tanks empty. Seatings are to be designed to ensure uniform support to the pressure vessel having due regard to deflections of the hull structure in a seaway. When the cargo is to be carried at temperatures below ambient, provision is to be made for expansion and contraction.

7206 The supports and securing arrangements should also be capable of withstanding a longitudinal acceleration of 0,5 g.

7207 Suitable arrangements are to be made for sealing the weather deck in way of openings for the cargo tanks.

7208 The spaces containing the cargo tanks are to be provided with means for access from above the weather deck.

7209 Ventilation systems for the spaces containing cargo tanks are to be independent of other ventilation systems, and means are to be provided to enable any single compartment to be isolated. Details, including the positioning of exhaust outlets, are to be submitted.

7210 Means are to be provided to enable the air in the cargo tank spaces, pump and compressor rooms to be sampled to detect any leakage.

Cross-reference

7211 For cargo tanks and their mountings see J 7 and E 12.

DREDGERS, HOPPER DREDGERS, SAND CARRIERS, HOPPER BARGES AND RECLAMATION CRAFT

Section 80

GENERAL

Application

8001 These Rules apply to non-self-propelled and self-propelled steel hopper barges and to steel dredgers, hopper dredgers, sand carriers and reclamation craft constructed with their main propulsion machinery and/or sand pumps or dredging machinery (other than grab cranes) placed within the main hull structure.

Ships which have their machinery placed on a shallow raft rather than within a hull will have their scantlings specially considered.

8002 The scantlings and arrangements of Dredgers, Hopper Dredgers, Sand Carriers, Hopper Barges and Reclamation Craft are to be as required by D 1 to D 34, except where otherwise stated in D 80 to D 90.

8003 Ships of unusual form or proportions or intended for unusual dredging methods will receive individual consideration on the basis of the general standards of the Rules.

Dredgers which resemble drilling rigs, or similar offshore structures, in their design or mode of operation, will be considered under the Rules for such structures.

8004 If the ratio of length to depth exceeds sixteen or the ratio of breadth to depth exceeds four, increased scantlings may be required to ensure that the hull deflections do not become excessive.

Stability

8005 Attention is drawn to the thixotropic properties of certain types of dredged material such that the ship's motions can cause the spoil to shift within a hopper space resulting in undesirable changes in trim or angles of heel. This can be particularly dangerous in vessels with closed top hoppers. See also 8008 (j).

Distribution of Continuous Longitudinal Material

8006 The midship scantlings are generally to extend over 0,4L amidships, or over the length of the hoppers, whichever is the greater, and are to be reduced gradually to those permitted at the ends except where otherwise required

by the Rules. Arrangements are to be made to avoid a sudden change in section at the ends of longitudinal hopper or well bulkheads.

Equivalents

8007 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted. Scantlings based on approved computer grillage calculations may be accepted if the stress and deflection values are considered suitable for the items concerned. See D 9013.

Plans

8008 Plans and calculations, as applicable, covering the following items are to be submitted in addition to the normal ship plans:—

- (a) Sections through hoppers, wells, pump rooms and dredging machinery spaces.
- (b) Hopper and well bulkheads and associated weirs.
- (c) Scarphing arrangements at hopper and well ends.
- (d) Outline arrangement and main scantlings of "A" frames, gantries, positioning spuds, hopper doors and similar items, the strength and integrity of which directly affect the hull structure of the vessel.
- (e) Support structure in way of "A" frames, positioning spuds and other dredging structures.
- (f) Seats of dredging machinery and pumps.
- (g) If dredging equipment is stored during voyages, plans of any special arrangements for dismantling, storage and re-assembly.
- (h) Longitudinal strength calculations, including shear stress values and details of proposed loading conditions including densities of spoil.
- A full set of stability data which is to be placed on board the ship. See B 101.

When it is intended that ships are to be classed 100A1 or 100A1 restricted service, but while operating in sheltered waters or within easy access of such waters, in reasonable

weather (see B 115 to B 117), they may be loaded to a draught greater than that which would be assigned under the International Load Line Convention for unrestricted international or similar voyages, then particulars of the draught desired and the associated loading conditions and structural arrangements are to be submitted for approval. Stability data for these deep draughts is to be included with that required under (j) above, but see B 101.

Definitions

8009 Length L is the distance, in metres (feet), on the load waterline at draught d, from the foreside of the stem to the afterside of the rudderpost, or to the centre of the rudderstock if there is no rudderpost. L is not to be less than 96 per cent and need not be greater than 97 per cent of the extreme length on the summer load waterline.

On ships classed A1 protected waters service for which a load waterline is not established by the International Load Line Convention method, the length is to be measured on the deepest waterline at which the ship is designed to operate.

On sea-going vessels with unusual stern arrangement, or with an unusual bow arrangement associated with a dredging draught in excess of the summer load line draught, the length L will be specially considered.

8010 Breadth B is the greatest moulded breadth, in metres (feet), excluding any localized bulge on the hull associated with the attachment or handling of the dredging gear.

8011 Draught d is the summer draught, in metres (feet), as established by the method described in the International Load Line Convention, measured from top of keel.

8012 Draught d_m is the maximum draught, in metres (feet), at which the ship is designed to operate. It is to be measured amidships from the top of keel and is not to be taken as less than d.

Section 81

LONGITUDINAL STRENGTH

8101 L = length of ship as defined in D 8009, in metres (feet).

 C_b = the moulded block coefficient at dredging draught d_m or 0,045L, whichever is the greater but is not to be taken as less than 0,60.

The block coefficient is to be determined using the length L. See also 8103.

C_{b1} = the moulded block coefficient at the ballast or part loaded draught, but is not to be taken as less than 0,60. The block coefficient is to be determined using length L. See also 8103.

B = moulded breadth, in metres (feet).

SWBM_D = the maximum still water bending moment under dredging conditions, in tonnes metres (tons feet), at draught d_m.
 The distribution of fuel, stores and fresh water is to represent typical dredging conditions and these are to be submitted for approval and shown in the loading booklet supplied to the ship. See D 302 and D 304.

SWBM_B = the maximum still water bending moment, in tonnes metres (tons feet), hogging or sagging in ballast or part loaded condition at draught d or less (see D 302 to D 305). When a dredger is arranged with two hoppers then account is to be taken in the calculation of SWBM_B of either one of these hoppers being empty unless such loading is expressly forbidden in the loading booklet supplied to the ship.

f = 0,65 for ships classed 100A1 without restriction having a length 120 m (394 ft) or less. Ships over 120 m (394 ft) will be specially considered.

= 0,60 for ships classed 100A1 restricted service.

= 0,55 for ships classed A1 protected waters service

 $\mathsf{F} = 0.44$ for ships classed 100A1 without restriction.

= 0,32 for ships classed 100A1 restricted service.

= 0,17 for ships classed A1 protected waters service.

K = values given in Table D 3.1.

$$\begin{split} {\rm M} = {\rm f~K~B~(C_b + 0.7) \times 10^5~cm^3} \\ {\rm (f~K~B~(C_b + 0.7) \times 10^3~in^2~ft)}. \end{split}$$

 $\mathbf{M_1} = 0.65 \text{ K B } (\mathbf{C_{b_1}} + 0.7) \times 10^5 \text{ cm}^3$ $(0.65 \text{ K B } (\mathbf{C_{b_1}} + 0.7) \times 10^3 \text{ in}^2 \text{ ft}).$

Section Modulus

8102 The section modulus at deck at side is not to be less than the greatest of the values given in Table D 81.1 as applicable.

8103 When the still water bending moment and block coefficient are being calculated, any water within hopper spaces or sand holds should be regarded as added weight, while that in dredging ladder wells and spud wells should be regarded as lost buoyancy.

8104 The section modulus at keel is to be not less than 7 per cent greater than that required by 8102 at deck at side.

8105 The section modulus at the top of continuous coamings may be 5 per cent less than that required at deck at side by 8102. The lever y used to calculate this modulus is to be measured to the top of coaming. The modulus requirements of 8102 must still be complied with at deck at side.

8106 Centreline box keels within the hopper spaces may normally be regarded as 100 per cent effective provided that they are effectively scarphed to the vertical keels or equivalent structure at each end of the hopper spaces.

Continuous coamings fitted above longitudinal bulkheads may normally be regarded as 100 per cent effective. Continuous coamings which are not supported by longitudinal bulkheads are to be assumed 80 per cent effective, the full modulus required by 8104 must, however, still be obtained. When an erection is fitted the requirements of D 310 and D 16 apply.

Extent of Midship Modulus

8107 The modulus derived as above is generally to extend over the full length of all hoppers and sand holds in hopper dredgers, hopper barges and sand carriers.

On other dredgers and reclamation craft the modulus is generally to be maintained for 0,4L amidships, but the extent may need to be increased if the design and loading condition of a particular ship results in its maximum bending moment occurring other than at amidships.

8108 If any dredging equipment has to be unshipped, lowered or otherwise specially arranged or stowed before the vessel proceeds on a sea-going voyage, this fact is to be marked on the data sheets and diagrams submitted for approval and is to be clearly stated in the loading booklet supplied to the ship.

Section 82

DECK PLATING

Symbols

8201 L = Length of ship, in metres (feet).

t = plate thickness, in mm (in).

s = spacing of beams or longitudinals, in mm (in).

TABLE D 81.1

MODULUS AT DECK AT SIDE	APPLICABILITY
(a) M cm ³ (M in ² ft)	all ships
(b) $FM + 72 SWBM_D cm^3$ $\left(FM + \frac{SWBM_D}{8 \cdot 8} in^2 ft\right)$	 (i) all ships where L ≥ 50 m (164 ft), (ii) all hopper dredgers, hopper barges and sand carriers classed 100A1, irrespective of length L, including those for restricted service, (iii) all hopper dredgers and sand carriers classed Al protected waters service when length of hopper is less than 0,5L, irrespective of length L.
(c) $0.44 \text{ M}_1 + 92 \text{ SWBM}_{\text{B}} (\text{C}_{\text{b}1} + 0.2) \text{ cm}^3$ $\left(0.44 \text{ M}_1 + \text{SWBM}_{\text{B}} \left(\frac{\text{C}_{\text{b}1} + 0.2}{6.9}\right) \text{ in}^2 \text{ ft}\right)$ or $0.88 \text{ M}_1 + 45.5 \text{ SWBM}_{\text{B}} (\text{C}_{\text{b}1} + 0.2) \text{ cm}^3$ $\left(0.88 \text{ M}_1 + \text{SWBM}_{\text{B}} \left(\frac{\text{C}_{\text{b}1} + 0.2}{13.9}\right) \text{ in}^2 \text{ ft}\right)$ whichever is the greater	 (i) all ships ≥ 50 m (164 ft) in length classed 100A1 without restriction, (ii) sand carriers ≥ 50 m (164 ft) in length classed 100A1, restricted service when d_m > d.

Strength Deck Outside Line of Openings

8202 Dredgers, hopper dredgers and hopper barges classed 100A1 without a restricted service notation are to have the minimum thicknesses required by D 1 to D 34 increased by 2 mm (0.08 in) for those areas of the strength deck outside line of openings which are exposed to the weather.

Ships classed 100A1 restricted service should have scantlings exactly as in D 1 to D 34.

Ships classed A1 protected waters service may have the minimum thicknesses as given in D 1 to D 34 for all plating outside line of openings reduced by 1 mm (0.04 in), with an overall minimum of 5 mm (0.20 in).

8203 The minimum value of s used in the formulæ for deck plating thickness may be taken as 550 mm (21.65 in) for all ships with a restricted service notation.

Strength Deck Plating Forward and Within Line of Openings

8204 The thickness of strength deck plating for 0.1L from the ends of the vessel and also amidships within the line of openings is not to be less than that for cargo ships, but in addition, such plating that is within 0.4L amidships is to have a thickness not less than $t = \frac{s}{100}$ mm (in).

Strengthening for Local Impacts

8205 Additional thickness may be required for those areas of deck which are liable to be subjected to regular, heavy, impact loads such as could occur when maintaining or inspecting large items of dredging gear, etc.

It is recommended that consideration be given to increasing the plating thickness in these areas to

$$t = \frac{s}{50} \text{ mm (in)}$$

with a minimum t = 10 mm (0.04 in).

Section 83

SHELL PLATING

Symbols

8301 L = Length of ship, in metres (feet).

D = depth moulded to the uppermost continuous deck, in metres (feet).

s = spacing of frames or longitudinals, in mm (in). B = moulded breadth, in metres (feet).

d = draught (see D 8011), in metres (feet).

 $d_{m} = dredging draught (see D 8012), in metres (feet).$

Keel

8302 On ships over 50 m (164 ft) in length where there is a centreline well, or where hopper doors are fitted on the vessel's centreline, i.e., where no centreline box keel is fitted in a hopper, then a keel strake is to be fitted on each side of the well or hopper door opening. The width of each keel strake is to be not less than half that required for a centreline keel nor less than 400 mm (15.75 in). The thickness of each keel strake is to be not less than the thickness required for a centreline keel.

Bottom Shell

8303 The minimum thickness of bottom shell plating amidships on hopper dredgers and hopper barges classed 100A1 without service restrictions is to be 15 per cent greater than that required for dry cargo ships. The thickness of bottom shell plating on vessels classed A1 protected waters service is to be not less than:—

$$\frac{\text{s L }\sqrt{\text{D}}}{20\,000} + 5 \text{ mm} \qquad \left(\frac{\text{s L}\sqrt{\text{D}}}{119\,000} + 0.2 \text{ in}\right)$$

or that required for dry cargo ships, whichever is the lesser, but with an overall minimum thickness of 6 mm (0.24 in).

Operating Aground

8304 Dredgers, hopper dredgers and reclamation craft intended or expected to operate while aground or to be frequently permitted to ground during the course of service are to have shell plating thicknesses increased by 20 per cent over the dry cargo ship minimum requirements, and in no case is the thickness so derived to be less than 8 mm (0.32 in).

Unless specifically stated otherwise by the Owner, it should be assumed that non-self-propelled reclamation craft, dredgers of the non-self-propelled hydraulic pipeline cutterhead type and non-self-propelled dipper bucket type are also intended to operate aground.

Ships with Chines

8305 On ships arranged with two chines each side, the bilge plating should generally be calculated from the bottom plating formulæ.

On hard chine ships flanged chines will not generally be approved, but where a chine is formed by knuckling the shell plating, the radius of curvature, measured on the inside of the plate, is not to be less than ten times the plate thickness.

8306 Where a solid round chine bar is fitted the bar diameter is to be not less than three times the thickness of the thickest abutting plate.

8307 Where welded chines are used the welding is to be built up as necessary to ensure that the shell plating thickness is maintained across the weld.

Extent of Midship Thickness Requirements

8308 Where hoppers extend outside 0,4L amidships the thicknesses required for the bottom shell amidships are to be maintained for at least two frame spaces beyond the ends of the hoppers before being tapered to the end thicknesses.

Bottom Openings

8309 The corners of hopper door openings and of bucket and ladder wells are generally to be parabolic or elliptical on all ships where L is greater than 50 m (164 ft) and should generally be rounded on smaller ships.

On ships where L is greater than 90 m (295 ft) the arrangement of hopper and well corners within 0,5L amidships should generally be as required for deck hatch corners. The sealing arrangements for hopper doors may lie within the line of the corners provided the construction is such as to avoid high stress concentrations in the structure.

Side Shell

8310 On ships classed A1 protected waters service the thickness of the side shell throughout, including at ends, may be reduced 20 per cent from that required by D 5 provided that the shear stress requirement of 8312 is satisfied.

8311 Where high compressive loads occur in the shear strake the thickness may require to be increased to minimize the likelihood of buckling.

8312 For side shell shear stress requirements for sea-going ships, see D 507. For ships classed A1 protected waters service the stress is not to exceed 12 kg/ mm² (7.65 ton/in²).

Swim Ends

8313 The plating of swim ends is to have a thickness not less than that required for the bottom shell up to the waterline at draught d. It is to have a thickness not less

than that required for side shell in the areas more than 1 m (3.28 ft) above the waterline at draught d_m. In intermediate areas the thickness may be tapered from the bottom to the side shell requirements.

Section 84

BOTTOM STRUCTURE

Symbols

8401 L = Length of ship, in metres (feet).

B = breadth of ship, in metres (feet).

D = depth of ship, in metres (feet).

 $d_m = dredging draught (see D 8012)$, in metres (feet).

s = frame spacing, in mm (in).

S₁ = spacing of transverses supporting longitudinals, in metres (feet).

S₂= span of floors, in metres (feet).

t = plate thickness, in mm (in).

Application

. 8402 This Section provides for longitudinal or transverse framing of the bottom structure of ships with single or double bottoms. A double bottom is to be provided in ships of 90 m (295 ft) in length or over as follows:—

- (a) on trailing suction hopper dredgers:-
 - between the collision bulkhead and the forward end of the hopper or well,
 - (ii) between the after bulkhead of the forward hopper and forward bulkhead of the after hopper on twin hopper ships.
- (b) on trailing suction side caster dredgers not fitted with hoppers:—

for 0,25L measured aft from the collision bulkhead.

The double bottom may, however, be interrupted locally, or fitted with wells in way of dredging pumps and other equipment. Where such openings are large their scantlings and arrangements will be specially considered.

DOUBLE BOTTOMS

8403 The Rule thickness of centre girders may be reduced by 2 mm (0.08 in) on vessels classed A1 protected waters service.

The minimum scantlings applicable to dry cargo ships are however, to be complied with.

8404 Special consideration will be given to the scantlings of floors, longitudinals and plating supporting the bottom of spaces intended to carry spoil on sand carriers.

8405 The Rule thickness of side girders may be reduced by 1 mm $(0\cdot04$ in) on ships classed for restricted service.

8406 The requirements of D 10 (Strengthening of Bottom Forward) need not be applied to ships classed A1 protected waters service.

 $8407\,$ For ships operating aground, see D 8408 and D 8412 to D 8414.

Double Bottom Structure with Transverse Framing

8408 Plate floors may be fitted at every frame or may be spaced not more than 3,05 m (10.0 ft) apart with the shell and inner bottom plating between these floors supported by bracket floors. However, plate floors are to be fitted at every frame in the following areas:—

- (a) as required for dry cargo ships, see D 910,
- (b) below holds and hoppers from which dredged material will be discharged by grabs,
- (c) in main propulsion and dredging machinery rooms and in peak tanks,
- (d) throughout in vessels intended to operate while aground,
- (e) for three frame spaces at the ends of hoppers and dredging wells.

Double Bottom Structure with Longitudinal Framing

8409 The section modulus of bottom longitudinals and inner bottom longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{S_1^2 s H}{K} cm^3 (in^3)$$

where H = (a) D for bottom longitudinals on ships classed 100A1 or 100A1 restricted service,

- (b) d_m for bottom longitudinals on ships classed A1 protected waters service,
- (c) height, in metres (feet), from the tank top to the deck at side, for inner bottom longitudinals (but need not exceed d_m on ships classed A1 protected waters service) except that, in sand carriers, H for inner bottom longitudinals is to be measured to the upper weir in spaces intended to carry dredged spoil,

- K = (a) 77 (1755) for inner bottom longitudinals below holds intended for dredged spoil,
 - (b) 74 (1680) for bottom longitudinals on ships expected to operate while aground,
 - (c) 120 (2730) for (i) bottom longitudinals for ships classed 100A1 and 100A1 restricted service other than ships expected to operate while aground. (ii) inner bottom longitudinals in machinery spaces on ships classed 100A1,
 - (d) 150 (3410) for bottom longitudinals on ships classed A1 protected waters service and for inner bottom longitudinals other than (i) those below holds intended for dredged spoil, and (ii) in machinery spaces on ships classed 100A1.
- s_1 = spacing of transverses, in metres (feet), and is not to be taken as less than 1,85 m (6·0 ft).

8410 The spacing of transverses is generally to be as for dry cargo ships but is not to exceed 4,0 m (13·12 ft). Below main dredging machinery the transverses are generally to be spaced not more than 1000 mm (39·4 in) apart.

8411 The ends of longitudinal girders under dredging machinery are to be tapered off or efficiently scarphed into other longitudinal structural items.

Strengthening for Operating Aground

8412 Ships intended or expected to operate while aground or to be frequently permitted to ground during the course of service are to have their double bottom structure additionally strengthened.

8413 Where such ships are transversely framed the floors in double bottoms are to be plate floors throughout and vertical stiffening is to be arranged to give panel widths not exceeding 1,25 m (49 in). Additional side girders are to be fitted such that the girder spacing does not exceed 2,5 m (8 \cdot 2 ft) and the additional stiffeners required by D 515 are to be extended and fitted throughout the flat of bottom.

Where the span of floors between a hopper space and the ship's side exceeds 3.75 m ($12 \cdot 3 \text{ ft}$) a longitudinal girder is to be fitted.

8414 Where ships are longitudinally framed the plate floors are generally to be spaced not more than 1,85 m $(6\cdot1)$ ft apart.

These floors are to be associated with longitudinal girders spaced not more than 2,5 m (8 \cdot 2 ft) apart.

SINGLE BOTTOMS TRANSVERSELY FRAMED

8415 Abreast of dredging wells and hoppers the minimum depth of floor at its inboard end is not to be less than $40 (S_3 + d_m)$ mm $(0.48 (S_3 + d_m)$ in),

where
$$S_3 = \frac{B + S_2}{2} m$$
 (ft)

S₂ = actual span of the floor measured between support points, in metres (feet).

The thickness of the web and area of the face plate are to be as required by SD 8 in the Rules for Small Ships at present being prepared.

8416 The scantlings of single bottom floors, extending the full width of the ship, are to comply with SD 8 (in the Rules for Small Ships) irrespective of the length of the vessel.

Floors below dredging pumps or similar items which could induce large concentrated loads or large dynamic forces, may require to be of increased strength.

Floors may be recessed locally in way of dredging pumps, etc., provided suitable compensation is arranged.

8417 The spacing of intercostals and longitudinal side girders is to be such as to ensure continuity of strength at bulkheads, ends of hoppers and wells and at ends of machinery seats so far as is practicable. (See also SD 8 in the Rules for Small Ships.) An intercostal is to be fitted in the buoyancy space abreast the hopper opening when the distance between the hopper opening and the ship's side exceeds 4,0 m (13·12 ft).

Strengthening for Operating Aground

- 8418 Ships intended or expected to operate while aground or to be frequently permitted to ground during the course of service are to have their bottom structure additionally strengthened as follows:—
 - (a) Floors are to be fitted with vertical stiffeners spaced not more than 1,5 m (59 in) apart.
- (b) Side girders are to be spaced not more than 2,2 m (7·25 ft) apart. The additional longitudinals required by D 515 are to be extended all fore and aft throughout the flat of bottom.

SINGLE BOTTOMS LONGITUDINALLY FRAMED

8419 The section modulus of bottom longitudinals is not to be less than:—

$$\frac{I}{v} = \frac{S_1^2 s d}{K} cm^3 (in^3)$$

where S_1 = spacing of transverses, in metres (feet), and is not to be taken as less than 1,85 m (6·0 ft),

K = (a) 74 (1680) on ships expected to operate while aground,

- (b) 120 (2730) on ships classed 100A1 or 100A1 restricted service other than those expected to operate while aground,
- (c) 150 (3410) on ships classed A1 protected waters service other than those expected to operate while aground.

8420 The spacing of transverses is generally not to exceed 4.0 m (13·12 ft).

These transverses are to be supplemented by brackets:—

- (a) on the ship's centreline, or each side of dredging wells where there is no structure on the centreline, the brackets are to be spaced not more than 1250 mm (49·2 in) apart and are to extend outboard to the first longitudinal, port and starboard. The longitudinals supported by the brackets may be calculated using a nominal transverse spacing of 1,60 m (5·25 ft).
- (b) on ships where the sides are transversely framed, the brackets are to be fitted at every frame and are to extend inboard to the first longitudinal on the flat of bottom. This longitudinal is to be based on a span equal to the spacing of the transverses.

The thickness of these intermediate brackets is not to be less than:—

$$0.25B + 1.85\sqrt{d_m} \text{ mm} (0.003B + 0.04\sqrt{d_m} \text{ in}).$$

8421 In areas of high shear loading the thickness and stiffening of the web plates on transverses, etc., may have to be increased.

The depth of transverses is to be not less than 2,5 times the depth of the slot for the bottom longitudinals and the thickness of the web plates is to be not less than 8 mm (0.32 in).

8422 Bottom transverses in hopper side buoyancy tanks in way of hopper cross ties are to have a depth of not less than $28B + 205\sqrt{d_m}$ mm $(0.336B + 4.45\sqrt{d_m}$ in).

Their arrangement, scantlings and end connections are to be such as to provide proper continuity of strength across the ship. 8423 The transverses are to be fitted with stiffeners in way of every shell longitudinal. The stiffeners should, in general, be equivalent to flat bars with a depth one-eighth of the transverse at that point and a thickness not less than the thickness of the transverse.

Strengthening for Operating Aground

8424 On ships intended to operate while aground the bilge longitudinals are to be as required for bottom longitudinals.

8425 The stiffening on the web plates of transverses is to be such that, in general, the sizes of the panels nearest the shell plating do not exceed $80 \ t \times 80 \ t$, where t is the actual web thickness.

8426 Ships intended to operate while aground are to have additional side girders fitted such that their spacing does not exceed 2,2 m (7·22 ft) and the spacing of transverses is to be closed up, or intermediate transverses are to be fitted, to give spacing of transverses not exceeding 2,5 m (8·2 ft) outboard of wells or 1,85 m (6·1 ft) elsewhere.

Section 85

HOPPER AND WELL STRUCTURE

Symbols

8501 h = head, in metres (feet), measured to the upper edge of the hatch or hopper coaming or to 0,5 m (1.64 ft) above the sill of the uppermost overflow weir, whichever is the lower.

t = plate thickness, in mm (in).

 $d_m = dredging draught (see D 8012)$, in metres (feet).

D = moulded depth to uppermost continuous deck, in metres (feet).

s = spacing or panel width, in mm (in).

ρ = specific gravity or stowage rate of water or hopper contents. The value assumed for the specific gravity of dredged spoil should not generally be less than 1,86. The value used in the calculation of scantlings is to be clearly marked on the relevant plans.

A₁ = cross-sectional area of flange or stiffener, in cm² (in²) including coaming plating.

 l_{θ} = unsupported length of stiffener, in metres (feet).

Application

8502 This Section provides for:-

- (a) horizontally and vertically stiffened boundary bulkheads to hoppers, and holds intended for dredged spoil, to ladder wells and to spud wells,
- (b) protection against flooding in the event of the ladder well or adjacent bottom plating being damaged by objects dredged up by bucket dredgers, and
- (c) continuity of transverse strength in hoppers and wing tanks abreast of hoppers.

Hopper and Well Bulkheads

Plating

8503 The minimum thickness of hopper and sand carrier hold bulkheads is to be the thickness required by D 19 for deep tanks,

or 10 mm (0·40 in) for grab dredgers or 8,5 mm (0·34 in) elsewhere whichever is the greater.

These thickness requirements also apply to the plating of watertight box keels as well as to hopper end and side bulkheads.

The value of ρ used in the calculations and the height(s) of the overflow weir(s) are to be clearly shown on the midship section plan.

Attention is drawn to the high rate of wear that can occur on hopper bulkheads and it is recommended that an additional corrosion allowance of 3 mm (0·12 in) be added on areas subject to particularly onerous conditions. When such an allowance is added, the fact should be marked on the relevant plans.

8504 The thickness of plating forming the sides and ends of bucket ladder wells is not to be less than:—

$$t = 0.0055 \, s \sqrt{d_m} + 3.0 \, mm \, (0.00304 \, s \sqrt{d_m} + 0.12 \, in).$$

In no case, however, is the side plating to have a thickness less than 12 mm (0·47 in) nor is the well end plating to have a thickness less than 8,5 mm (0·34 in). Plating forming the boundaries of suction pipe ladder wells is generally to be as required for shell plating. Corrosion allowance on well end plating below bucket ladders may be 2 mm (0·08 in).

8505 The thickness of hopper bulkheads and of ladder well bulkheads may require to be increased where high shear forces are present.

8506 Bulkheads forming the boundaries of spud wells are to be of increased strength. Each case will be considered on its merits, but in general such bulkheads should have a thickness of not less than 12 mm (0.47 in).

Stiffeners

8507 Stiffeners are generally to be as required by D 19 for deep tanks, but with h and ρ as defined in 8501.

End connections are generally to be as required by D 18.

8508 Structure supporting spud well plating and bulkheads below and in way of "A" frames and dredging machinery supports is to be of substantial construction, account being taken of the dynamic loads likely to occur with the dredging machinery in operation.

Girders and Web Frames

8509 The section modulus and inertia of horizontal girders supporting stiffeners on hopper and ladder well boundaries are, in general, to be as required by D 19 for deep tanks, with h and ρ as defined in 8501 and with span S_G , for horizontal girders supporting vertical stiffeners on longitudinal bulkheads measured between bulkhead bracket and bulkhead bracket, i.e., ignoring any struts which may be fitted between hopper girder and shell stringer.

Alternatively, the section modulus of these horizontal girders may be reduced by 40 per cent from the formula value if struts are fitted on alternate frames between the hopper girder and a shell stringer. These struts should generally be horizontal and are to have a sectional area as required for pillars by D 14 with ρ assumed 0,537 m³/tonne (19·32 ft³/ton) and h measured from the inboard end of the strut to the height defined in 8501.

8510 Web frames and girders are to be as required by D 19 with ρ and h as defined in 8501.

8511 When non-watertight bulkheads are fitted in the side buoyancy tanks in hopper dredgers, sand carriers or hopper barges, the thickness of the plating is to be not less than:—

- (a) 6,5 mm (0·26 in) or
- (b) 5.35 mm + 0.024 L mm (0.21 + 0.00029 L in), whichever is the greater.

Where the bulkhead is in the form of a wash bulkhead, the openings should be arranged so that, in general, the distance from lightening holes to any slots cut to accommodate side shell or bulkhead longitudinals is at least equal to 1,5 times the depth of the slot. The edges of large openings are to be stiffened.

Ladder Well Cofferdams

8512 Ladder wells of trailing suction dredgers are to be isolated from the remainder of the dredger's structure by local cofferdams at least 600 mm (23.6 in) wide, or are to be otherwise protected so as to prevent serious flooding due to the well side plating being breached by the ladder structure should this be damaged in service.

Ladder wells of bucket dredgers are to be isolated by cofferdams, the extent and widths of which are to be sufficient to contain any damage to the well side bulkheads or bottom shell plating that could result from the impact of large objects brought up in the dredge buckets. In way of the buckets the cofferdam may be extended outboard in the form of a local watertight double bottom.

Continuity of Strength

8513 Arrangements are to be made to ensure continuity of strength at the ends of longitudinal hopper and well side bulkheads. In general, the design should be such that the bulkheads are connected to bottom and deck girders by means of large suitably shaped brackets arranged to give a good stress flow at their junctions with both the girders and the bulkheads.

Cross Members in Hopper Spaces

8514 Cross members are to be fitted within the hopper space in line with the bottom and side shell transverses and with the bulkheads in the side buoyancy spaces. Cross members need not be fitted at every frame, but their spacing is not to exceed 4,0 m (13·12 ft).

Where a box keel is fitted on the centreline, webs are to be fitted within the box keel to ensure proper continuity of strength across the vessel in way of the hopper cross member. See 8519.

8515 The upper edge of the hopper lower cross members should, in general, be at a height of not less than D/4 above the keel in vessels with the number 100 in their character of classification. The lower edge should be as low as practicable after allowing for the proper design of hopper doors, suction passages, etc.

8516 Lower cross members may be fabricated from flat plate suitably stiffened or may take the form of a hollow box, generally of triangular cross-section.

8517 The scantlings of box-type cross members should be determined from the requirements for hopper bulkheads where applicable.

8518 When flat plate lower cross members are fitted the thickness of the web is not to be less than:—

$$t = 0.7 B + 3 mm (t = 0.0084 B + 0.12 in)$$

or 8.5 mm (0.34 in), whichever is the greater.

The cross-sectional area of the cross member web after deducting access openings, lightening holes, etc., is not to be less than 6 $h_w s$ cm² (0.0864 $h_w s$ in²).

where $h_{\mathbf{W}} = \text{height}$, in metres (feet), of the uppermost hopper overflow weir above the keel,

s = spacing of the cross member webs, in metres (feet).

The upper edge of the cross member is to be stiffened by means of a tube having an outside diameter not less than 30 S mm (0.36 S in) and a thickness equal to the minimum required cross tie web thickness, or by an equivalent flange or structure,

where S = span, in metres (feet), of the upper edge of the cross member (to the centreline box girder if fitted).

The lower edge of the cross member is also to be suitably stiffened.

The cross member web is to be fitted with stiffeners, spaced not more than 80 t mm (in) apart having a modulus of not less than 0,04 s S² cm³ (0.00576 s S² in³),

where t = actual thickness of the cross member web, in mm (in),

s = spacing of stiffeners, in mm (in),

S = span of stiffeners, in metres (feet).

8519 The webs required within centreline watertight box keels may have a thickness 3,5 mm (0·14 in) less than that required for the hopper cross members with which they are associated, but their minimum thickness is not to be less than 6,5 mm (0·26 in).

Hopper Upper Cross Members

8520 Cross members spanning hopper spaces at or above deck level are to be designed on the basis of actual loads carried, including dynamic factors if applicable, and 60 per cent end fixity. Total stress f_c is not to exceed 12 kg/mm² (7.62 ton/in²), bending stress f_b is not to exceed 7,6 kg/mm² (4.83 ton/in²), shear stress f_s is not to exceed 7 kg/mm² (4.44 ton/in²), and $f_c = \sqrt{f_b^2 + 3f_s^2}$.

They should, in general, be connected to the centreline box keel by one or more pillars, when such a keel is fitted.

Pillars within Hoppers

8521 Pillars are generally to comply with the requirements of D 14, account being taken of the maximum forces that can be applied by rams or other gear fitted for the purpose of activating hopper doors or valves.

Continuous Coamings

8522 Continuous coamings are to have a plate thickness of not less than 8,5 mm (0·34 in). A minimum thickness of 10 mm (0·40 in) is recommended for hopper coamings on grab dredgers.

8523 When the depth of the coaming exceeds 80 t the plating is to be stiffened by one or more horizontal members so spaced that the width of the upper panel of plating does not exceed 65 t and the width(s) of the lower panel(s) do(es) not exceed 80 t.

When the coaming is stiffened with flat bar members they are to have a width not less than $\frac{l_{\,\Theta}}{25}$ and a thickness not less than 0,05 times their breadth, or 8,5 mm (0·34 in) whichever is the greater. They are to have a minimum

inertia I =
$$\frac{{l_{\,\mathrm{e}}}^2\,\mathsf{A}_1}{0.5}\,\mathrm{cm}^4$$
 $\left(\frac{{l_{\,\mathrm{e}}}^2\,\mathsf{A}_1}{34\cdot7}\,\mathrm{in}^4\right)$

where A₁ and I includes the coaming plating from mid-panel above to mid-panel below the stiffener,

 $l_{\rm e}=$ spacing of the brackets required by 8525.

Where stiffeners other than flat bars are used they are to have at least the same minimum thickness and inertia as is required for flat bars.

8524 The upper edge of the coaming is to be stiffened by a fabricated flange, box girder or equivalent structure having a width not less than $\frac{l_e}{20}$, and an inertia not less

than I =
$$\frac{l_e^2 A_1}{0.35}$$
 cm⁴ $\left(\frac{l_e^2 A_1}{24 \cdot 3} \text{ in}^4\right)$

where A₁ and I include the coaming plating down to midpanel below,

 $l_{\,\mathrm{e}} = \mathrm{spacing}$ of brackets required by 8525.

The thickness and/or attachments of the stiffening member are to be such as to minimize any likelihood of local instability under compression loading.

8525 The coamings are to be supported by substantial brackets spaced generally not more than 3 m (9.84 ft) apart when the coamings have a height of more than 600 mm (23.5 in), nor more than 2,5 m (8.2 ft) when the coamings have a height of more than 1,0 m (39.5 in), but on longitudinally framed ships the brackets should be

arranged in way of each deck transverse. Additional brackets may be required in way of the ends of hopper upper cross ties especially those which themselves support hopper door operating rams or similar equipment.

8526 The ends of continuous coamings are to be well scarphed into the ship's structure at the ends of the hopper or sand hold. Unless longitudinal deckhouse bulkheads are fitted in this area, the coamings are to be extended beyond the end of the hopper or sand hold opening for a distance of at least one frame space or 1,5 times the coaming height, whichever is the greater.

Section 86

SIDE FRAMING

Longitudinal Side Framing

8601 The minimum moduli of side longitudinals are to be as required by D 6 for ships classed 100A1 or 100A1 restricted service but may be reduced by 5 per cent on ships classed A1 protected waters service.

8602 The spacing of transverses and web frames supporting side longitudinals may, on request, be permitted to be increased up to a maximum of 4 m (13·12 ft).

8603 The modulus of web frames and transverses supporting side longitudinals amidships on hopper dredgers and sand carriers classed 100A1 restricted service may be 5 per cent less than that rquired by D 6.

On all ships classed A1 protected waters service the modulus of web frames and transverses may be 10 per cent less than that required by D 6.

8604 Transverses and web frames supporting side longitudinals abreast of hoppers and sand holds are to have an inertia of not less than:—

where S = span of the member, in metres (feet), measured between span points.

8605 For wash bulkheads fitted in lieu of web frames abreast hoppers and sand holds, see D 8511.

8606 The end connections of side transverses and web frames to deck and bottom transverses abreast of hoppers or sand holds are to be arranged to prevent shear buckling of the members' webs. In general, stiffeners are to be arranged

such that web panels in way of the junction do not exceed $80 \, t \times 60 \, t$ in size, where t is the actual web plate thickness.

Transverse Side Framing

8607 The modulus of side frames amidships may be reduced by 8 per cent of ships classed A1 protected waters service.

8608 For arrangements in way of fenders, see D 9012.

Panting Arrangements

8609 The requirements of D 11 need not be complied with on ships classed A1 protected waters service.

Section 87

BULWARKS, FREEING PORTS, SCUPPERS AND SANITARY DISCHARGES AND SIDE SCUTTLES

8701 In general, bulwarks are not to be fitted in way of open hoppers. In no case are bulwarks to be fitted in way of open hoppers where the hopper weirs discharge onto the deck instead of into enclosed overflow trunks.

Bulwarks are not to be fitted in way of open hatches on sand carriers.

If bulwarks are fitted, freeing ports are to be provided throughout their length and of sufficient size to permit the immediate overboard discharge of any spoil that may spill out of the hopper in the event of the dredger rolling excessively.

Hopper Weirs and Overflows

8702 All hoppers and the holds of sand carriers are to be arranged to permit the safe and efficient overboard discharge of excess water in all weather conditions in which the ship is classed to operate.

In hopper dredgers and sand carriers over 90 m (295 ft) in length and in all ships classed 100A1 without restriction, the hold and hopper overflows are to be arranged via enclosed overflow trunks so designed as to keep the decks of the ship clear of spoil and water.

8703 Where a hopper dredger or sand carrier operates at the maximum draught that could be assigned in accordance with the International Load Line Convention 1966, the overflow arrangements fitted should ensure that when the hopper of the dredger or the hold of the sand carrier is loaded this draught is not exceeded. In this condition, the trim and bending moments should be acceptable.

Where a hopper dredger having releasing arrangements for cargo dumping, e.g., bottom doors, etc., is permitted by an Administration to be assigned a freeboard less than that which could be assigned by the International Load Line Convention 1966, the Society should be satisfied with regard to the following:—

- (a) The structural strength and bending moments are acceptable for the deeper draught indicated.
- (b) The dredger operates in a zone of operation and such conditions of weather as are considered appropriate.

Adequate arrangements are to be fitted so as to prevent overloading under any condition of loading having due regard to trim.

The size and position of the overflows should be confirmed by a loading trial, which should be carried out when the hopper or sand hold is loaded with dredgings of the same density as is likely to be loaded in service.

8704 The cutting of overflow discharge trunk openings in the sheer strake is to be avoided whenever practicable.

In ships over 70 m (229.6 ft) in length, hopper overflow discharge trunk openings are not to be cut within 800 mm (31.5 in) of the upper edge of the sheer strake. They are to have corner radii of not less than 150 mm (6 in) and suitable compensation is to be arranged. In no case is a discharge trunk to pierce the sheer strake in way of discontinuities such as breaks of superstructure.

Protection of Pipes and Valves

8705 In all areas where damage might be likely, all side scuttles, scuppers and discharges including their valves, controls and indicators are to be well protected. Consideration is to be given to the likelihood of impact damage to scuttles and discharges due to barges coming along side, and to scuppers becoming blocked by sand or other spoil which may spill onto the decks or other areas being drained.

8706 Consideration will be given to requests for relaxation of requirements relating to scuttles, scuppers and discharges on ships classed A1 protected waters service.

Section 88

WELDING

8801 The welding in hopper spaces is to be as given in Table D 88.1. The welding in all other areas, including hold spaces in sand carriers, is to be as for dry cargo ships.

8802 For welding of shell chines, see D 8307.

Section 89

EQUIPMENT

General

8901 The regulations governing the assignment of the figure 1 for equipment are contained in B 203.

8902 For ships engaged in special services, an equipment number differing from the requirements of Table D 34.1 may be approved by the Committee if considered suitable for the particular service on which the ship is to be engaged. See also 8907.

8903 When determining the value of the equipment numeral Δ = moulded displacement, in tonnes (tons), to the summer load waterline, i.e., at draught d. See also D 8103.

8904 On ships classed 100A1 restricted service, the weight of the bower anchors and the length and diameter of the bower anchor chain cables may be derived from Table D 34.1, using the values two grades below the calculated equipment number. No reduction will normally be allowed on stream anchors, tow ropes or mooring ropes on these ships, but a tow rope is not required when such ships are unpowered.

A stream anchor is not required on ships fitted with positioning spuds.

8905 On ships classed A1 protected waters service, the weight of the bower anchors and the diameter of the bower anchor chain cables may be derived from Table D 34.1, using the value for an equipment number one-half of the ship's calculated equipment number. Two anchors are to be carried on powered ships and one anchor is to be carried on unpowered (but manned) ships. The length of each of the bower anchor chain cables is to be not less than 2L m (ft) or ten times the maximum depth at which the ship is designed to dredge, whichever is the greater, but need not exceed the length required for ordinary cargo ships with the same anchor weight.

A towline is not required but the mooring ropes are to be derived directly from Table D 34.1 for the ship's actual equipment numeral.

8906 On ships classed A1 protected waters service, wire rope may be substituted for the chain cable of the bower anchors. This wire rope is to have a breaking strength not less than 1,5 times that required for the chain cable. It should normally consist of six strands of an "equal lay" construction over an independent wire rope core. ("Cross lay" strands over a fibre core will not generally be acceptable).

TABLE D 88.1

HOPPERS	*WELD FACTOR	REMARKS	
Bulkhead boundary connections	0,39 (0·55) 0,35 (0·50)	At bottom and sides At deck and coamings	
Bulkhead stiffeners	0,12 (0.17)	THE STATE OF THE S	
Girders and web frames to bulkheads	$0,21 \ (0\cdot 30)$ $0,26 \ (0\cdot 37)$	Generally clear of end brackets In way of end brackets	
Girder webs to face bars	0,12 (0-17)		
Girder web stiffeners to web	0,12 (0.17)		
Girders to girder brackets	0,26 (0.37)	Generally continuous	
Stiffeners to end brackets	_	See Table D 32.1, Note 6	
Beam webs to face bars	0,12 (0.17)	Continuous	
Cross members to bulkheads and keel	0,39 (0.55)	Continuous	
Pillar and connections	0,35 (0.50)		
Hopper door hinges	0,44 (0.63)	Full penetration generally required	

^{*}Weld sizes in metric units are based on throat thickness and in British units on leg length.

Unmanned Barges

8907 On unmanned barges, only one anchor need be fitted when L is 30 m (98 ft) or more. When L is less than 30 m (98 ft) no anchor need be carried.

The length of anchor cable is not to be less than 40m (131 ft) or 2L m (ft), whichever is the greater, on each anchor fitted.

(Note. In general, if desired, all anchors and cables may be omitted, in which case the number 1 will be omitted from the character of classification).

8908 Each unmanned barge is to be supplied with two mooring lines when the length L is less than 65 m (213 ft) and three mooring lines when the length is 65 m (213 ft) or above. The length of each mooring line is to be not less than 2L m (ft) where L is the length of the ship, nor less than 80 m (262 ft), but need not exceed that required for manned ships. The strength of each line is to be derived from the ship's equipment number as for sea-going ships.

8909 When the number 1 is to be omitted from the character of classification (see 8907), the length and number of mooring lines may be reduced but the required strength is to be maintained. In all cases, the number and length of mooring lines are to be suitable to the service, and in no case is such a barge to carry less than two mooring lines each having a length of not less than 45 m (147.6 ft).

Working and Stowing Anchors and Cables

8910 On unpowered ships, the windlass may be hand operated.

8911 When wire rope is used instead of chain for the anchor cable, it is to be stored on a properly designed drum or reel.

8912 Fairleads intended for use with wire rope cable are to be designed to minimize wear and to avoid kinking or other similar damage occurring to the rope. Fairleads should, in general, be fitted with rollers having a diameter not less than eleven times the diameter of the anchor cable, but a ratio of not less than 15,7 to 1 is recommended.

Section 90

MISCELLANEOUS ITEMS

Watertight Bulkheads

9001 The number of watertight bulkheads is to be not less than as required for dry cargo ships. Their positioning should be such that one extends the full width of the ship at each end of the hopper spaces. See also D 8512.

9002 The Committee will be prepared to consider proposals to dispense with one or more of the watertight bulkheads in that part of the ship in way of hoppers. In particular, watertight bulkheads need not be fitted within hoppers and an increased spacing of bulkheads in the spaces abreast of hoppers and sand holds will generally be accepted provided that:—

- (a) suitable structural compensation is arranged, and
- (b) the stability is checked in the damaged condition.

Exposed Casings

9003 Exposed casings on ships classed A1 protected waters service are to have scantlings as required for deck-houses on dry cargo ships classed 100A1.

Dredging Machinery Seats

9004 The seats supporting the main dredging machinery are to be at least as substantial as those required for the main propulsion machinery for dry cargo ships.

Continuity between the longitudinal and transverse members of main engine seats and the ship's bottom structure is to be arranged where practicable.

9005 Where floors are cut away below dredging pumps, they should be fitted with face bars and special care is to be taken to minimize stress raising details and to ensure good workmanship.

9006 Where d_m equals or exceeds the draught corresponding to B-60 freeboards on ships classed 100A1, direct access is not permitted to the machinery spaces (including dredging pump rooms) from the freeboard deck.

Doors may be fitted in exposed casing bulkheads provided they lead to a space which is of equivalent strength to the casing and is separated from the machinery space by a second weathertight door.

Rudders and Sternframes

9007 Where bucket dredgers are arranged with bucket ladders at their stern, the ship's rudders are to be kept well clear of the buckets so as to minimize the likelihood of the rudders being damaged by large items which may be dredged up.

9008 The solepiece on ships classed A1 protected waters service is to be so designed that:—

- (a) The transverse bending stress does not exceed 8 kg/mm² (5·1 ton/in²) assuming that the mean force acting on the rudder is 10 (V+3)² kg/m² (2·05 (V+3)² lb/ft²).
- (b) The cross-sectional area is not less than 18 cm² (2·8 in²).
- (c) The thickness is not less than two-thirds of its width at any point.

9009 On ships classed A1 protected waters service, the rudder stock diameter may be 84 per cent of that required for ships classed 100A1.

On non-self-propelled ships, k is to be taken as 0,226.

Ladder Wells

9010 When ladder wells are incorporated into a dredger, hopper dredger, or sand carrier, such that the length of the well exceeds 1,5 times the width of the deck remaining on each side of the well, the portions of the vessel on each side of the well are to be adequately cross connected in the region of their free ends, unless the design of the ship renders this impracticable, in which case alternative arrangements are to be made to avoid high stress concentrations at the inboard end of the well.

Dredging Gear

9011 When masts or derrick posts support dredging gear which will be subjected to vibration or other dynamic loads in addition to its true weight, then this must be taken into account in the calculations. The dynamic multiplier should be taken between two and three according to the type of machinery and gear used.

Fenders

9012 Dredgers designed to work in conjunction with hopper barges are to be fitted with permanent rubbing strakes or fenders extending down to their lowest normal operating waterline. On transversely framed vessels it is recommended that the side structure in way of the lower edge of the fender be reinforced by a stringer and/or cross ties. It is recommended that when wooden fenders are fitted to dredgers operating in tropical sea water, the fenders be cut just above the deepest working waterline and a gap left sufficient to prevent water soaking up into the fenders.

Direct Calculations

9013 Consideration will be given to any proposals to base the scantlings of any ships covered by these Sections on direct calculations. In such cases the proposed loadings, stress levels and corrosion allowances are to be submitted for consideration at an early stage in the design. When such calculations are made for major items such as longitudinal bulkheads, main transverses, etc., the Society may also require that the effect of shear deflections be taken into account.

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Chapter E

PUMPING AND PIPING

Section 1

PLANS

101 The following plans are to be submitted for consideration:—

General pumping arrangements, including air and sounding pipes and any cross flooding pipes and fittings. (Shipbuilder's plan.)

Pumping arrangements at the forward and after ends of oil tankers and drainage of cofferdams and pump rooms.

General arrangement of cargo piping in tanks and on deck of oil tankers.

Piping arrangements for cargo oil (F.P. 60°C (140°F) or above, closed cup test).

Bilge, ballast and oil fuel pumping arrangements in the machinery space, including the capacities of the pumps on bilge service. In the case of passenger ships the criterion numeral, as defined in the International Convention for the Safety of Life at Sea-1960 is to be stated together with the number of flooded compartments which the ship is required to withstand under damage conditions.

Arrangement of oil fuel pipes and fittings at settling and service tanks.

Arrangements of oil fuel piping in connection with oil burning installations and oil fired galleys.

Oil fuel and cargo oil overflow systems, where these are fitted.

Arrangement of boiler feed system.

Arrangement of compressed air systems for main and auxiliary essential services.

Arrangement of cooling water systems for main and auxiliary essential services.

Oil fuel settling, service and other oil fuel tanks not forming part of the ship's structure.

Above plans of piping are to be diagrammatic.

Arrangement and dimensions of main steam pipes with details of flanges, bolts and weld attachments and particulars of the material of pipes, flanges bolts and electrodes.

NOTE. Plans additional to the above should not be submitted unless the arrangements are of a novel or special character affecting classification.

See Chapter L for Control Engineering Equipment, See Chapter R(B) for Provisional Rules for Plastic Pipes.

See Chapter R(D) for Guidance Notes on Metal Pipes for Water Services.

Section 2

GENERAL

201 In power driven ships the pumping arrangements according to the division of compartments, rise of floor and other conditions are to be as detailed in these Rules which apply to passenger ships, cargo and other ships except where otherwise stated.

202 While the arrangements satisfy the requirements of the International Convention for the Safety of Life at Sea-1960, attention should be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

203 The Committee will be prepared to give consideration to special cases or to arrangements which are fully equivalent to those required by these Rules. Consideration will also be given to the pumping arrangements of small ships and ships to be assigned class notations for restricted or special services.

(For pumping arrangements of non-self-propelled ships, see E 10.)

BILGE AND BALLAST

204 All ships are to be provided with efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least one suction when the ship is on an even keel and is either upright or has a list of not more than 5 degrees. For this purpose wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

In passenger ships the pumping plant is to be capable of draining any watertight compartment under all practical conditions after a casualty, whether the ship is upright or listed.

Hold Drainage

205 In ships having only one hold, and this over 33,5 m (110 ft) in length, bilge suctions are to be fitted in suitable positions in the after half-length, also in the forward half-length of the hold.

206 Where close ceiling or continuous gusset plates are fitted over the bilges, arrangements are to be made whereby water in a hold compartment may find its way to the suction pipes.

207 Where the inner bottom plating extends to the ship's side, the bilge suctions are to be led to wells placed at the wings. If the tank top plating has inverse camber, a well is also to be fitted at the centreline.

Bilge wells are to be formed of steel plates and are not to be less than 0,17 m³ (6 ft³) capacity. In small compartments, steel bilge hats of reasonable capacity may be fitted.

In passenger ships wells in double bottom tanks are not to extend downwards more than necessary; the depth of the well is in no case to be more than the depth less 460 mm (18 in) of the double bottom at the centreline, nor shall the well extend below the horizontal plane referred to in D 909.

Where access manholes to bilge wells are necessary, they are to be fitted as near to the suction strums as practicable.

208 Access to the bilge suction strum of a hold well should not be obtained by means of a manhole in the machinery space watertight bulkheads or tank top plating in the machinery space or tunnel if this can be avoided.

Where, however, this arrangement is necessary, the watertight manhole cover should be of hinged type and an instruction plate, in raised letters, should be affixed in a well lighted position, to the effect that this door must be kept shut, except when access is required. In passenger ships these arrangements are not permissible.

209 The intactness of the machinery space bulkheads, and of tunnel plating which is required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck. These scuppers may, however, be led into a strongly constructed scupper drain tank situated in the machinery space or tunnel but closed to these spaces and drained by means of a suction of appropriate size led from the main bilge line through a screw-down non-return valve.

The tank air pipe is to be led to above the bulkhead deck and provision is to be made for ascertaining the level of water in the tank.

Where one tank is used for the drainage of several watertight compartments, the scupper pipes are to be provided with screw-down non-return valves.

210 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage either by hand or power pump bilge suctions.

If, however, these compartments are adequately isolated from the adjacent 'tween decks, they may be drained by scuppers not less than 38 mm (1.5 in) bore, discharging to the tunnel and fitted with self-closing cocks situated in well lighted and visible positions. These arrangements are not applicable to passenger ships unless specially approved in relation to sub-division considerations.

Drainage from Refrigerated Cargo Spaces

211 Provision is to be made for the continuous drainage of the inside of all insulated chambers and cooler trays.

212 Drains which are led from lower holds and cooler trays situated on the tank top are to be fitted with liquid sealed non-return bilge traps.

Drains from 'tween deck chambers and from cooler trays which are situated well above the tank top are also to be fitted with liquid sealed traps, but the non-return valves may be omitted if desired. For insulation of scupper pipes, see E 418.

- 213 Where drains from separate chambers join a common main, the branch pipes are each to be provided with a liquid sealed trap.
- 214 The liquid sealed traps are to be of adequate depth and arrangements are to be made for ready access to the traps for cleaning and refilling with brine.
- 215 Sluices, scuppers or drain pipes which would permit drainage from compartments outside the insulated chambers into the bilges of the latter are not to be fitted.
- 216 Screwed plugs or other means for blanking off scuppers draining insulating chambers and cooler trays are not to be fitted.

If, however, it is specially desired by the Owners to provide means for temporarily closing these scuppers, they may be fitted with shut-off valves controlled from readily accessible positions on a deck above the load waterline.

Machinery Space-Bilge Drainage

217 The bilge drainage arrangements in the machinery space are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the ship is on an even keel and is either upright or has a list of not more than 5 degrees. One of these suctions is to be a branch bilge suction, i.e., a suction connected to the main bilge line, and the other is to be led direct from an independent power pump. Examples of the necessary arrangements are detailed in 218 to 220.

In passenger ships the drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty whether the ship is upright or listed.

Where it is intended that the engine and/or boiler rooms will not be continuously manned at sea, an approved bilge level alarm system is to be provided in these spaces to give warning of flooding (see L 207). The alarm system is to operate audible and visible signals at the station from which the machinery is controlled which should be in direct communication with the bridge. When control is being effected from the bridge only, the alarms must operate in the engine room control station and in the Engineer Officers' accommodation.

- 218 Where the double bottom extends the full length of the machinery space and forms bilges at the wings, it will be necessary to provide one branch and one direct bilge suction at each side.
- 219 Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells of not less than 0,17 m³ (6 ft³) capacity, situated one at each side.

In passenger ships the depth of bilge wells is to comply with the requirements of 207.

220 Where there is no double bottom and the rise of floor is not less than 5 degrees, one branch and one direct bilge suction are to be led to accessible positions as near the centreline as practicable.

In ships where the rise of floor is less than 5 degrees and in all passenger ships additional bilge suctions are to be provided at the wings.

- 221 Additional bilge suctions may be required for the drainage of depressions in the tank top formed by crank pits, or other recesses, by tank tops having inverse camber or by discontinuity of the double bottom.
- 222 In ships in which the propelling machinery is situated at the after end of the ship, it will generally be necessary for bilge suctions to be fitted in the forward wings as well as the after end of the machinery space, but each case will be dealt with according to the size and structural arrangements of the compartment.
- 223 In ships propelled by electrical machinery, special means are to be provided to prevent the accumulation of bilge water under the main propulsion generators and motors.
- 224 Where the machinery space is divided by watertight bulkheads to separate the boiler room(s) or auxiliary engine room(s) from the main engine room, the number and position of the branch bilge suctions in the boiler room(s) and auxiliary engine room(s) are to be the same as for cargo holds.

In addition to the branch bilge suctions an independent power pump direct bilge suction is to be fitted in each compartment. Similar provision is to be made in separate motor rooms of electrically propelled ships.

225 In passenger ships each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. Where two or more such suctions are provided there is to be at least one suction on each side of the space.

Machinery Space-Emergency Bilge Drainage

226 In steamers, the main circulating water pump to each main engine is to be fitted with an emergency bilge suction, i.e., "bilge injection", which is to be additional to the bilge suctions detailed in 217 to 225. This suction, which is to have a diameter of at least two-thirds that of the pump suction, is to be led to a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve having the spindle so extended that the handwheel is not less than 460 mm (18 in) above the bottom platform.

If two pumps are provided for one engine, each capable of supplying sufficient cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

Where main circulating water pumps are not suitable for bilge pumping duties, alternative arrangements may be submitted for consideration. 227 In motorships, the emergency bilge suction is to be led to the main cooling water pump or to the main cooling water suction line. The suction is to be of the same size as the suction branch of the cooling water pump and the valve nameplate is to be marked "For emergency use only".

Alternatively, the emergency bilge suction may be led to the largest available power pump which is not fitted with a direct bilge suction and is to be of the same size as the suction branch of the pump. This pump is to have a capacity greater than that required for a bilge pump, and if it is of the self-priming type the direct bilge suction on the same side of the ship as the emergency suction may be omitted, except in passenger ships.

This emergency bilge suction is additional to the bilge suctions detailed in 217 to 225 and is to comply with the requirements of 226 as regards location and valve arrangements.

Tunnel Drainage

228 The tunnel well is to be drained by a suction from the main bilge line. In all ships including passenger ships this well may extend to the outer bottom.

229 Where the tank top in the tunnel slopes down from aft to forward, a bilge suction is to be provided at the forward end of the tunnel, in addition to the tunnel well suction required by 228.

Sizes of Bilge Suction Pipes

230 The diameters of bilge suction pipes are not to be less than required by the following formulæ, to the nearest 5 mm (0.25 in):—

MAIN BILGE LINE

$$d_{m} = \sqrt{2,78 L (B + D)} + 26 mm \quad (1)$$

$$d_{m} = \sqrt{\frac{L (B + D)}{2500} + 1 in}$$

In no case is the diameter of the main bilge line to be less than required for any branch bilge suction.

Branch Bilge Suctions to Cargo and Machinery Spaces

$$d_b = \sqrt{4,63 \text{ C (B + D)}} + 26 \text{ mm}$$
 (2)

$$\left({{{\rm{d}}_{\rm{b}}} \! = \! \sqrt {\frac{{{\rm{C}}\left({{\rm{B}} + {\rm{D}}} \right)}}{{1500}} \! + \! 1\;{\rm{in}}} } \right)$$

where d_m = internal diameter of main bilge line, in mm (in),

d_b = internal diameter of branch bilge suction, in mm (in),

L = Rule length of ship, in metres (feet),

B = Rule breadth of ship, in metres (feet),

D = moulded depth to bulkhead deck, in metres (feet),

C = length of compartment, in metres (feet).

No bilge suction pipe is, however, to be less than 50 mm (2 in) bore.

DIRECT BILGE SUCTIONS, OTHER THAN EMERGENCY SUCTIONS

231 The direct bilge suctions in the main engine room and the direct bilge suctions in large separate boiler rooms, motor rooms of electrically propelled ships and auxiliary engine rooms are not to be of a diameter less than required for the main bilge line.

Where the separate machinery spaces are of small dimensions, the sizes of the direct bilge suctions to these spaces will be specially considered.

For sizes of emergency bilge suctions, see 226 and 227.

232 In oil tankers and similar ships where the engine room pumps do not deal with bilge drainage outside the machinery space, the diameter of the main bilge line may be less than required by formula 230 (1), provided the cross-sectional area is not less than twice that required for the branch bilge suctions in the machinery space.

233 The area of each branch pipe connecting the bilge main to a bilge distribution chest is not to be less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

234 The bilge suction pipe to the tunnel well is not to be less than 65 mm (2.5 in) bore, except in ships not exceeding 61 m (200 ft) in length, in which case it may be 50 mm (2 in) bore.

Bilge and General Service Pumps

235 For ships other than passenger ships at least two power bilge pumping units are to be provided in the machinery space. In ships of 91,5 m (300 ft) in length and under, one of these units may be worked from the main engines and the other is to be independently driven. In larger ships both units are to be independently driven.

Each of these units is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of bilge of not less than 122 m/minute (400 ft/minute) under ordinary working conditions, but where one unit is of slightly less than this capacity, the deficiency may be made good by an excess capacity of the other unit.

236 TABLE OF CAPACITIES

TABLE E 2.1

Bore of bilge pipe	Capacity of each pumping	Bore of bilge pipe	Capacity of each pumping
mm (in)	unit in m ³ /hour or ton/hour	mm (in)	unit in m³/hour or ton/hour
51 (2)	15	133 (5.25)	103
57 (2.25)	19	140 (5.5)	113
63.5(2.5)	23	146 (5.75)	124
70 (2.75)	28	152 (6)	135
76 (3)	34	159 (6.25)	146
82,5 (3.25)	40	165 (6.5)	158
89 (3.5)	46	171 (6.75)	171
95 (3.75)	53	178 (7)	183
102 (4)	60	184 (7.25)	197
108 (4.25)	68	190 (7.5)	210
114 (4.5)	76	197 (7.75)	224
$121 (4 \cdot 75)$	84	203 (8)	239
127 (5)	93	209 (8.25)	254

237 Each unit may consist of one or more pumps connected to the main bilge line, provided their combined capacity is adequate.

238 In ships other than passenger ships a bilge ejector in combination with a high pressure sea water pump may be accepted as a substitute for an independent bilge pump required by 235.

239 For passenger ships at least three power bilge pumps are to be provided, one of which may be operated from the main engines. Where the criterion numeral is 30 or more, one additional independent power pump is to be provided. A main engine driven pump may be replaced by an independent pump. Each pump is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of main bilge pipe of not less than 122 m/minute (400 ft/minute).

For location of pumps, see 256.

Self-priming Pumps

240 All power pumps which are essential for bilge services are to be of self-priming type, unless an approved central priming system is provided for these pumps. Details of this system are to be submitted.

Cooling water pumps having bilge ejection connections need not be of self-priming type.

Pump Connections

241 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

242 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any of the pumps so connected is unaffected by the other pumps being in operation at the same time.

Direct Bilge Suctions

243 The direct bilge suctions in the machinery space(s) are to be led to independent power pump(s), and the arrangements are to be such that these direct suctions can be used independently of the main bilge line suctions.

Main Bilge Line Suctions

244 Suctions from the main bilge line, i.e., branch bilge suctions, are to be arranged to draw water from any hold or machinery compartment of the ship, excepting small spaces such as those mentioned in 262, where manual pump suctions are accepted, and are to be of not less size than required by formula 230 (2). (For special arrangements for oil tankers, see E 1112 to E 1117).

Pipe Systems and their Fittings

245 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks.

To effect this requirement, the bilge connections to any pump having also suctions from the sea and from tanks should be made either by means of non-return valves or cocks which cannot permit communication between the bilges and the sea or compartments in use as tanks.

246 Screw-down non-return valves are to be provided in the following fittings:—

Bilge valve distribution chests;

Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line;

Direct bilge suctions and bilge pump connections to main bilge line.

247 Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried. This does not, however, exclude a bilge ejection connection, a connecting pipe from a pump to its suction valve chest, or a deep tank suction pipe suitably connected through a change-over device to either a bilge, ballast or oil line.

248 Suctions for bilge drainage in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes.

249 The open ends of bilge suctions in holds and other compartments outside machinery spaces and tunnels, are to be enclosed in strum boxes having perforations not more than 10 mm (0.375 in) diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

The distance between the foot of all bilge tail pipes and the bottom of the bilge or well is to be adequate to allow a full flow of water and to facilitate cleaning.

250 All valves and cocks in connection with bilge, ballast and fresh water suction pipes are to be fitted with legible nameplates, and, unless otherwise specifically mentioned in the Rules, are to be fitted in places where they are at all times readily accessible.

251 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space and tunnel platforms.

Where it is not practicable to avoid the fittings being situated at the starting platform or in passageways, they may be situated just below the platform, provided readily removable traps or covers are fitted and nameplates indicate the presence of these fittings.

If relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform.

252 Bilge suction pipes are not to be carried through double bottom tanks if it is possible to avoid doing so.

Bilge pipes which pass through these tanks are to be of substantial strength and are to be tested, after fitting, to the same pressure as the tanks through which they pass.

253 In way of deep tanks for water ballast, fresh water, oil fuel or cargo oil, bilge pipes should preferably be led through pipe tunnels but, where this is not done, the pipes are to be of steel of heavy gauge with welded joints or heavy flanged joints. The number of joints is to be kept to a minimum.

Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the open ends of the bilge suction pipes in the holds are to be fitted with non-return valves of the special type approved for use in holds (see 266).

Tank piping, other than that of the deep cargo tank pumping system, is not to be situated within deep cargo oil tanks.

The pipes are to be tested, after fitting, to a pressure not less than the maximum head to which the tanks can be subjected.

254 Bilge, ballast and cooling water suction and discharge pipes are to be permanent pipes made in readily removable lengths with flanged joints, except as mentioned in 253, and are to be efficiently secured in position to prevent chafing or lateral movement.

Where lack of space prevents the use of normal circular flanges, details of the alternative methods of joining the pipes are to be submitted.

Long or heavy lengths of pipes are to be supported by bearers so that no undue load is carried by the flanged connections of the pumps or fittings to which they are attached.

Pipes for bilge, ballast and cooling water systems are to be made of cast iron, steel, copper or other approved material. Heat sensitive materials such as lead are not to be used.

255 Suitable provision for expansion is to be made in each range of pipes.

Expansion pieces of an approved type incorporating special quality oil resistant rubber or other suitable synthetic material may be used in cooling water lines in machinery spaces. Where fitted in sea water lines, they are to be provided with guards which will effectively enclose, but not interfere with, the action of the expansion pieces and will reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements.

Proposals to use such fittings in water lines for other services, including:—

- (a) ballast lines in machinery spaces, duct keels and inside double bottom water ballast tanks,
- (b) bilge lines inside duct keels only,

will be specially considered when plans of the pumping systems are submitted for consideration.

Bilge Drainage and Cross Flooding Arrangements for Passenger Ships in Damaged Condition

256 In passenger ships the power bilge pumps are, if practicable, to be placed in separate watertight compartments which will not readily be flooded by the same damage. If the engines and boilers are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as possible.

In passenger ships of 91,5 m (300 ft) or more in length or having a criterion numeral of 30 or more, the arrangements are to be such that at least one power pump will be available for use in all ordinary circumstances in which the ship may be flooded at sea. This requirement will be satisfied if:—

- (a) One of the pumps is an emergency pump of a submersible type having a source of power situated above the bulkhead deck or,
- (b) The pumps and their sources of power are so disposed throughout the length of the ship that, under any conditions of flooding which the ship is required by statutory regulation to withstand, at least one pump in an undamaged compartment will be available.
- 257 The bilge main is to be arranged so that no part is situated nearer the side of the ship than $\frac{\mathsf{B}}{\mathsf{5}}$ where B is the breadth of the ship.

Where any bilge pump or its pipe connection to the bilge main is situated outboard of the $\frac{B}{5}$ line then a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be arranged so that they are situated inboard of the $\frac{B}{5}$ line.

258 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than $\frac{B}{5}$ or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

259 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. If there is only one system of pipes common to all pumps, the necessary valves or cocks for controlling the bilge suctions must

be capable of being operated from above the bulkhead deck. Where in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions; in this case only the valves and cocks necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

260 All valves and cocks mentioned in the foregoing paragraphs which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

261 Where divided deep tanks or side tanks are provided with cross flooding arrangements to limit the angle of heel after side damage, the arrangements are either to be self acting or controlled from above the bulkhead deck.

Fore and After Peak Drainage

262 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, when hand pumps may be used.

The collision bulkhead is not to be pierced below the bulkhead deck in passenger and cargo ships by more than two pipes. The pipes are to be provided with screwdown valves capable of being operated from an accessible position above the bulkhead deck, the chests being secured to the bulkhead inside the fore peak. Indicators are to be provided to show whether the valves are open or shut.

Where the peaks are not used as tanks and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided the suction lift be well within the capacity of the pumps and in no case exceeds 7,3 m (24 ft).

Provision is to be made for the drainage of the chain locker and the watertight flat above the fore peak tank by hand or power pump suction. (For drainage of the flat above the after peak tank, see 210.)

Watertight Bulkhead and Tunnel Fittings

263 No drain valve or cock is to be fitted to the collision bulkhead.

Drain valves or cocks are not to be fitted to other watertight bulkheads, if alternative means of drainage are practicable. Where fitted, the valves and cocks are to be at all times readily accessible and are to be capable of being shut off from positions above the bulkhead deck. Indicators are to be provided to show whether the drains are open or shut. These arrangements are not permissible in passenger ships. (For drainage of stern compartments, see 210.)

264 Valve chests, cocks, pipes or other fittings attached direct to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts and not by bolts passing through clearance holes.

Alternatively, the studs or the bulkhead piece may be welded to the plating.

Deep Tanks

265 In the case of deep tanks which may be used for either water ballast or dry cargo, provision is to be made for blank flanging the water ballast filling and suction pipes when the tank is being used for the carriage of dry cargo and for blank flanging the bilge suction pipes when the tank is being used for the carriage of water ballast.

Change-over devices may be used for this purpose. (For arrangements when oil fuel or cargo oil is carried in deep tanks, see E 324.)

Hold Bilge Valves

266 Where non-return valves are fitted to the open ends of bilge suction pipes in cargo holds in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

Ship-side Valves and Fittings (other than those on Scuppers and Sanitary Discharges)

267 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating or to the plating of fabricated steel water boxes attached to the shell plating. These fittings are to be secured by bolts tapped into the plating and fitted with countersunk heads or by studs screwed into heavy steel pads fitted to the plating. The stud holes are not to penetrate the plating.

Distance pieces of short rigid construction, and made of approved material as required by 270, may be fitted between the valves and shell plating. Distance pieces of steel may be welded to the shell plating. Details of the welded connections and of fabricated steel water boxes are to be submitted.

Gratings are to be fitted at all openings in the ship's side for sea inlet valves and inlet water boxes. The net area

through the gratings is not to be less than twice that of the valves connected to the sea inlets and provision is to be made for clearing the gratings by use of low pressure steam or compressed air. (See 271.)

268 All suction and discharge valves and cocks secured direct to the shell plating of the ship are to be fitted with spigots passing through the plating, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating.

Blow-down valves or cocks are also to be fitted with a protection ring through which the spigot is to pass, the ring being on the outside of the shell plating.

269 Blow-down valves or cocks on the ship's side are to be fitted in accessible positions above the level of the working platform and are to be provided with indicators showing whether they are open or shut. Cock handles are not to be capable of being removed unless the cocks are shut, and if valves are fitted, the hand wheels are to be suitably retained on the spindle.

Sea inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions and, as far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut.

Provision is to be made for preventing any discharge of water into lifeboats.

The inlet valve spindles are to extend above the lower platform, and the hand wheels of the main injection and bilge injection valves are not to be situated less than 460 mm (18 in) above this platform.

270 All valves and cocks are to be of steel, bronze or other approved ductile material; ordinary cast iron is not acceptable. This requirement applies equally to inlet chests, distance pieces and other sea connections.

Material submitted for approval is to have an elongation not less than 12 per cent on a gauge length of $5,65\sqrt{S_o}$, where S_o is the actual cross-sectional area of the test piece.

All these fittings, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

271 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

Cross-reference

272 For sea connections for ships having notation for ice navigation, see H 509 to H511, and H 536 to H 537.

Miscellaneous Requirements

273 All pipes situated in cargo spaces, chain lockers or other positions where they are liable to mechanical damage are to be efficiently protected. (See D 2819, quoted at end of this Section, and D 2914, quoted at end of E 4.)

274 Wash deck pipes and discharge pipes from the pumps to domestic water tanks are not to be led through cargo holds if, as is generally the case, it is practicable to avoid doing so. Any proposed departure from this requirement is to be submitted.

275 So far as practicable, pipe lines, including exhaust pipes from oil engines, are not to be led in the vicinity of switchboards or other electrical appliances in positions where drip or escape of liquid, gas or steam from joints or fittings may cause damage to the electrical installation.

Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary.

Short sounding pipes to tanks should not terminate near electrical appliances. See E 413.

Extract from Chapter D for reference

Scuppers and Sanitary Discharges

D 2811 Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

D 2812 In ships over 150 m (492 ft) in length, scupper openings are not to be cut in the sheerstrake above deck level within 0,5 L amidships, and in no case in way of discontinuities such as breaks of superstructures. See D 510.

When scuppers or discharges are cut in the shell or superstructure sides compensation may require to be fitted.

D 2813 Scuppers and discharges which drain spaces below the freeboard deck or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers or to suitable sanitary tanks in the case of sanitary pipes. Alternatively, they may be led overboard provided the spaces drained are above the load waterline, and the pipes are fitted with efficient and accessible means of preventing water from passing inboard. See 2814.

D 2814 In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the freeboard deck. An indicator is to be fitted at the control position showing whether the valve is open or closed.

Where, however, the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,01L the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided the inboard valve is always accessible for examination under service conditions.

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,02L, consideration will be given to proposals for fitting a single automatic non-return valve without positive means of closing.

D 2815 Scuppers and discharge pipes originating at any level, which penetrate the shell more than 450 mm (17.5 in) below the freeboard deck or less than 600 mm (23.5 in) above the summer load waterline are to be fitted with an automatic non-return valve at the shell.

This valve, unless required by 2813, may be omitted provided the pipe thickness is not less than:—

$$\frac{\text{Diameter of pipe in mm}}{24} + 6.5 \text{ mm}$$

$$\left(\frac{\text{Diameter of pipe in inches}}{24} + 0.25 \text{ in}\right)$$

but need not exceed 12,5 mm (0.50 in).

D 2816 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors to be led overboard.

D 2817 Plans showing the arrangement of scuppers for draining refrigerated cargo compartments are to be submitted for consideration.

Materials for Valves, Fittings and Pipes

D 2818 All valves required by 2814, and shell fittings where no valves are required, are to be of steel, bronze or other approved ductile material; ordinary cast iron is not acceptable. Material submitted for approval is to have an elongation not less than 12 per cent on a gauge length of $5,65\sqrt{S_0}$, where S_0 is the actual cross-sectional area of the test piece.

All these items, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

The lengths of pipe attached to the required valves or elbow pieces are to be of galvanized steel of standard steam pipe quality or other equivalent approved material. See also F 706.

Protection of Pipes and Valves

D 2819 In all cargo spaces and other areas where damage might be likely, all scuppers and discharges including their valves, controls and indicators are to be well protected. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, fork lift trucks or similar items is a possibility.

Section 3

OIL FUEL AND CARGO OILS HAVING A FLASH POINT OF 60°C (140°F) OR ABOVE (CLOSED CUP TEST)

General

301 In addition to the special requirements detailed in this Section, the requirements of E 2 relating to bilge and ballast are to be complied with in so far as they are applicable to the drainage of tanks, oil bilges and cofferdams.

302 The flash point (closed cup test) of oil fuel for use in steam and motor ships classed for unrestricted service is in general not to be less than 60°C (140°F). For emergency generator engines a flash point of not less than 43°C (110°F) is permissible.

Fuels with flash points lower than 60°C (140°F) may be used in ships intended for service restricted to geographical limits where it can be ensured that the temperature of the machinery and boiler spaces will always be 10degC (18degF) below the flash point of the fuel. In such cases, safety precautions and the arrangements for storage and pumping will be specially considered. However, the flash point of the fuel is to be not less than 54°C (130°F) when supplied for oil fired boilers or 43°C (110°F) for oil engines unless specially approved.

When it is desired to carry a quantity of fuel having a flash point below 43°C (110°F) for special services, e.g., aviation spirit for use in helicopters, full particulars of the proposed arrangements are to be submitted for special consideration. For the burning of methane gas in methane tankers see Chapter R(A).

Oil Fuel Pumps and Oil Burning Appliances

303 In every ship where steam for the main propelling engines, or for auxiliary machinery which is required for essential services, is generated by burning oil fuel under pressure, there are to be not less than two oil burning units, each unit comprising a pressure pump, a suction filter, a discharge filter and a heater.

In two unit installations, each unit is to be capable of supplying fuel for generating all the steam required for essential services.

In installations of three or more units, the capacities and arrangements of the units are to be such that all the steam required for essential services can be maintained with any one unit out of action.

304 Unit pressure pumps for the oil burning system are to be entirely separate from the feed, bilge or ballast systems.

305 In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners and so arranged that one filter can be opened up when the other is in use. Similar or equivalent arrangements are to be provided in the fuel supply lines to main and auxiliary oil engines and gas turbines.

306 If oil fuel is sprayed by steam, means are to be provided to carry or make up the fresh water used for this purpose.

307 A starting-up oil fuel unit, including an auxiliary heater and hand pump, or other suitable starting-up device, which does not require power from shore, is to be provided.

Alternatively, where auxiliary machinery requiring compressed air or electric power is used to bring the boiler plant into operation, the arrangements for starting such machinery are to comply with H 608.

308 All pumps used in connection with oil fuel are to be provided with effective escape valves which are to be in close circuit, i.e., discharging back to the suction side of the pumps.

Escape valves are also to be fitted on the oil side of the heaters, discharging to the pump suction line, to the tray under the unit, or to other approved positions, and are to be adjusted to operate at a pressure of 3,5 kg/cm² (50 lb/in²) above that of the pump escape valve.

309 Where a power driven transfer pump is necessary for pumping up the settling tanks in motorships and steamships, a stand-by pump is to be provided and connected ready for use, or alternatively, emergency connections may be made to one of the unit pumps or to another suitable power driven pump.

Oil Pipes and Fittings

310 Pipes conveying heated oil under pressure are to be of seamless steel or other approved material having flanged couplings and placed in sight above the platform in well lighted parts of the stokehold or engine room.

The flanges are to be machined and the jointing material, which is to be impervious to oil heated to 150°C (300°F), is to be the thinnest possible, so that the flanges are practically metal to metal. The scantlings of the pipes and their flanges are to be suitable for at least 14 kg/cm² (200 lb/in²) working pressure, or the pressure to which the relief valves are adjusted, whichever is the greater.

The piping system is to be tested after jointing to twice the working pressure.

The thickness of the oil fuel pressure pipes is to be determined from the formulæ contained in E 512 and E 513.

311 The short joining lengths of pipes to the burners from the control valves at the boiler may have cone unions provided these are of specially robust construction.

Flexible pipes of approved material and design may be used for the burner pipes provided spare lengths, complete with couplings, be carried on board.

A quick-closing master valve is to be fitted to the oil supply to each boiler manifold suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control, having regard to the machinery arrangements and location of controls.

Provision is to be made by suitable non-return arrangements to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut off.

In the case of top-fired boilers, means are to be provided so that, in the event of flame failure, the oil fuel supply to the burners is shut off automatically and audible and visible warning is given. Any proposal to depart from this requirement in the case of small auxiliary top-fired boilers would be the subject of special consideration.

312 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be made of cast iron or steel, having flanged joints suitable for a working pressure of not less than 7 kg/cm² (100 lb/in²). The flanges are to be machined and the jointing material is to be impervious to oil. Where the pipes are 25 mm (1 in) bore, or less, they may be of seamless copper or copper alloy excepting those which pass through oil storage tanks. Oil pipes within the engine and boiler spaces are to be fitted where they can be readily inspected and repaired, and after jointing they are to be tested to 3,5 kg/cm² (50 lb/in²), or twice the maximum working pressure, whichever is the greater.

Valves and Cocks

313 The valves, cocks and their pipe connections are to be so arranged that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or

into tanks which can be used for the carriage of fresh water intended for boiler feed or for drinking.

In passenger ships provision is to be made for the transfer of oil fuel from any oil fuel storage or settling tank to any other oil fuel storage or settling tank in the event of fire or damage.

- 314 Every oil fuel suction pipe from a double bottom tank is to be fitted with a valve or cock.
- 315 Every oil fuel suction pipe from a storage, settling and daily service tank situated above the double bottom and every oil fuel levelling pipe within the boiler room or engine room is to be fitted with a valve or cock secured to the tank. In the case of fore peak tanks, these valves are to be fitted on the tank side of the bulkhead.

In the engine and boiler spaces, such valves and cocks are to be capable of being closed locally and from positions which will always be accessible in the event of fire taking place in these spaces. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

In the case of very small tanks consideration will be given to the omission of remote controls.

- 316 Every oil fuel suction pipe which is led into the engine and boiler spaces from a tank situated above the double bottom outside these spaces is to be fitted in the machinery space with a remote controlled valve, except where the valve on the tank is already remote controlled.
- 317 All valves and cocks forming part of the oil fuel installation are to be capable of being controlled from readily accessible positions which, in the engine and boiler spaces, are to be above the working platform.

Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

Oil fuel valves are to be so constructed as to prevent the possibility of any cover being slacked back or loosened when operating the valves. The valves and cocks are to be fitted with legible nameplates.

- 318 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in the case of the outlet valves or cocks on these tanks.
- 319 Open drains for removing the water from oil tanks are to be fitted with valves or cocks of self-closing type and suitable provision is to be made for collecting the oily discharge.

Oil Fired Galleys

320 The fuel oil tank is to be located outside the galley and is to be fitted with approved means of filling and venting. The fuel supply to the burners is to be controlled from a position which will always be accessible in the event of a fire occurring in the galley. The galley is to be well ventilated.

When liquefied petroleum gas is used similar provisions are to be made.

Filling Arrangements

321 In passenger ships, the filling station is to be isolated from other spaces and is to be efficiently drained and ventilated. Provision is to be made against over-pressure in the filling pipe lines and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

Alternative Carriage of Oil Fuel and Water Ballast

322 Where it is intended to carry oil fuel and water ballast in the same compartments alternatively, the valves or cocks connecting the suction pipes of these compartments with the ballast pump and those connecting them with the oil fuel transfer pump are to be so arranged that the oil may be pumped from any one compartment by the oil fuel pump at the same time as the ballast pump is being used on any other compartment.

Where settling or service tanks are fitted each having a capacity sufficient to permit 12 hours normal service without replenishment, the above requirement may be dispensed with.

323 Attention is drawn to the statutory regulations issued by National Authorities in connection with the International Convention for Prevention of Pollution of the Sea by Oil, 1954.

Deep Tanks for the Alternative Carriage of Oil, Water Ballast or Dry Cargo

324 In the case of deep tanks which can be used for the carriage of oil fuel, cargo oil, water ballast or dry cargo, provision is to be made for blank flanging the oil and water ballast filling and suction pipes, also the steam heating coils if retained in place, when the tank is used for dry cargo and for blank flanging the bilge suction pipes when the tanks are used for oil or water ballast.

If the deep tanks are connected to an overflow system the arrangements are to be such that liquid or vapour from other tanks cannot enter the deep tanks when dry cargo is carried in them.

Oily Bilge Drainage and Sediment Suctions

325 Provision is to be made for the drainage of oil gutterways, oil wells and cofferdams. (See D 1926 to D 1929, quoted at end of this Section.)

Fresh Water Piping

326 Pipes in connection with compartments used for storing boiler feed water are to be separate and distinct from any pipes which may be used for oil or oily water, and are not to be led through tanks which contain oil, nor are oil pipes to be led through boiler feed water tanks.

Similar precautions are necessary when the connections are such that fresh water carried in other tanks can be used as reserve feed water.

Service, Settling and other Oil Fuel Tanks

327 In general, the minimum thickness of the plating of these tanks, when they do not form part of the structure of the ship, is to be 5 mm (0·19 in), but in the case of very small tanks, the minimum thickness may be 3 mm (0·125 in).

For rectangular steel tanks of welded construction the plate thicknesses are to be not less than indicated in Table E 3.1. The stiffeners are to be of approved dimensions.

TABLE E 3.1

	1	Head from of Overflo	Bottom of 'w Pipe in m	Tank to To etres (feet)	р
Thickness of Plate in mm	2,5 (8)	3,0 (10)	3,7 (12)	4,3 (14)	4,9 (16)
(inches)	В	readth of I	anel in mm	(inches)	311
5 (0·19)	585 (22)	525 (20)		nas m	Liqui
6 (0·22)	725 (26) .	645 (23)	590 (21)		
7 (0·25)	860 (30)	770 (27)	700 (25)	650 (23)	
8 (0·31)	1000 (39)	900 (35)	820 (32)	750 (30)	700 (28)
10 (0·375)	1280 (48)	1140 (43)	1040 (39)	960 (36)	900 (34)

The dimension given in Table E 3.1 for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, washplates or the boundary plating of the tank.

Where necessary, stiffeners are to be provided and if the length of the stiffener exceeds twice the breadth of the panel, transverse stiffeners are also to be fitted, or, alternatively, tie bars are to be provided between stiffeners on opposite sides of the tank. On completion the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected but not less than 2,5 m (8 ft) above the crown of the tank.

Tanks in which the oil fuel is heated are to be provided with a suitable thermometer pocket.

Water Drainage from Settling Tanks

328 Settling tanks are to be provided with means for draining water from the bottom of the tanks.

If settling tanks are not provided, the oil fuel bunkers or daily service tanks are to be fitted with water drains (see 319).

Ventilation

329 The spaces in which the oil fuel burning appliances, and the oil fuel settling and service tanks are fitted, are to be well ventilated and easy of access.

Boiler Insulation and Air Circulation in Boiler Room

- 330 The boilers are to be suitably lagged. The clearance spaces between the boilers and tops of the double bottom tanks and between the boilers and the sides of the storage tanks in which oil fuel or cargo oil is carried, are to be adequate for the free circulation of air necessary to keep the temperature of the stored oil well below its flash point.
- 331 Where water tube boilers are installed, there should be a space of at least 760 mm (2.5 ft) between the tank top and the underside of the pans forming the bottom of the combustion spaces.
- 332 Smoke-box doors are to be shielded and well fitting, and the uptake joints made airtight.

Funnel Dampers

333 Dampers which are capable of completely closing the gas passages are not to be fitted to inner funnels of ships equipped for burning oil fuel only. In ships burning oil or coal alternatively, dampers may be retained if they are provided with a suitable device whereby they may be securely locked in the fully open position.

Steam Heating Arrangements

334 Where steam is used for heating oil fuel, cargo oil or lubricating oil, either in bunkers, tanks, heaters or separators, the exhaust drains are to discharge the condensate into an observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil (see E 1118).

- 335 The steam heating pipes in contact with oil are to be of iron, steel, approved aluminium alloy or approved copper alloy and are to be tested, after being fitted on board, to twice the maximum pressure to which they can be subjected.
- 336 The thickness of steel steam heating pipes is to be determined from the formulæ in E 512 and E 513.

Control of Pumps

337 The power supply to the oil fuel transfer and pressure pumps and to the cargo oil pumps is to be capable of being stopped from a position which will always be accessible in the event of fire taking place in the compartment in which they are situated, as well as from the compartment itself.

Precautions against Fire

- 338 Settling and daily service oil fuel tanks and oil fuel filters are not to be situated immediately above boilers or other highly heated surfaces.
- 339 Oil fuel pressure pipes are to be led, wherever practicable, remote from heated surfaces and electrical appliances, but where this is impracticable, the pipes are to have a minimum number of joints and are to be led in well lighted and readily visible positions.
- 340 The arrangement and location of short sounding pipes to oil tanks are to be in accordance with E 413. (For alternative sounding arrangements, see E 414.)
- 341 Water service pipes and hoses are to be fitted in order that the floor plates and tank top or shell plating in way of boilers, oil fuel apparatus or deep storage tanks in the engine and boiler spaces can at any time be flushed with sea water.
- 342 So far as is practicable, the use of wood is to be avoided in the engine rooms, boiler rooms and tunnels of ships burning oil fuel.
- 343 Drip trays are to be fitted at the furnace mouths to intercept oil escaping from the burners and under all other oil fuel appliances which require to be opened up frequently for cleaning or adjustment. The arrangements are to be such that a burner cannot be withdrawn unless the oil fuel supply to that burner is shut off and that the oil cannot be turned on unless the burner has been correctly coupled to the supply line.

For alternately fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

Separation of Cargo Oils from Oil Fuel

344 Pipes conveying vegetable oils or similar cargo oils are not to be led through oil fuel tanks, nor are oil fuel pipes to be led through tanks containing these cargo oils. (See D 1931, quoted at end of this Section.)

Refrigerated Cargo Spaces in way of Oil Storage Tanks

345 The insulation of all oil storage tank tops is to have an air space of 50 mm (2 in) provided between the underside of the insulation and the tank top plating and the supporting battens are to be arranged to provide free drainage to the bilges. Alternatively, the air space may be omitted, provided successive coatings of an approved oil impervious composition be applied to the upper surface of the tank top plating. The total thickness of the coating required will depend on the construction of the tank, the composition used and the method of application.

346 Riveted bulkheads of deep tanks intended for the carriage of oil are to be separated from refrigerated compartments by a cofferdam.

Provision is to be made for ventilating the cofferdam, the vents being led to the open air and their outlets being fitted with a wire gauze diaphragm which can be easily removed for renewal.

Where the tank bulkhead is wholly welded, including its boundary connections, the cofferdam may be omitted, provided successive coatings of an approved oil impervious composition be applied to the refrigerated compartment side of the tank bulkhead. The total thickness of the coating required will depend on the composition used and the method of application.

Extracts from Chapter D for reference

Protection and Drainage in Tanks Carrying Oil Fuel or Lubricating Oil

D 1926 Compartments carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying fresh or feed water. Oil fuel or lubricating oil compartments are to be similarly separated from those carrying vegetable oil. Cofferdams are to be suitably ventilated.

For tanks carrying vegetable and similar oils, see 1931.

D 1927 Gutterways are to be arranged at the foot of bulkheads in boiler rooms to ensure that leakage shall have free drainage to the wells or limbers.

D 1928 Drip trays or gutterways with suitable draining arrangements are to be provided for all tanks which do not form part of the hull structure, at pumps, valves and elsewhere where there is a possibility of leakage.

Drip trays are also to be fitted under oiltight decks, except if these are completely welded, when the drip trays need only be fitted over boilers and exhaust pipes.

D 1929 If cargo is carried in a compartment adjacent to an oil fuel settling tank which may be heated, the compartment side of the bulkhead or deck is to be insulated or equivalent arrangements provided.

Tanks carrying Vegetable and Similar Oils

D 1931 Deep or peak tanks carrying vegetable or similar oils are to be separated from those carrying oil fuel, lubricating oil or fresh or feed water by a cofferdam.

Cofferdams are not required between oil fuel double bottom tanks and deep tanks above provided the inner bottom plating is not subjected to a head of oil fuel.

Section 4

AIR, OVERFLOW AND SOUNDING PIPES

Air and Overfle Pipes

401 Air pipes are to be fitted at the opposite end of the tank to that at which the filling pipes are placed and/or at the highest part of the tank.

Where the tank top is of unusual or irregular profile special consideration will be given to the number and position of the air pipes.

Nameplates are to be affixed to the upper ends of all air pipes.

402 Air pipes to double bottom tanks, deep tanks extending to the shell plating or tanks which can be run up from the sea are to be led to above the bulkhead deck.

Air pipes to oil fuel and cargo oil tanks, cofferdams and all tanks which can be pumped up are to be led to the open. (For height of air pipes above deck, see D 2911, quoted at end of this Section.)

- 403 The open ends of air pipes to oil fuel and cargo oil tanks are to be situated where no danger will be incurred from issuing oil or vapour when the tank is being filled and each opening is to be furnished with a wire gauze diaphragm of incorrodible material which can be readily removed for cleaning or renewal.
- 404 Air pipes from lubricating oil storage tanks may terminate in the machinery space, provided the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

405 The closing appliances fitted to tank air pipes, in accordance with D 2912, are to be of a type which will prevent excessive pressure coming on the tanks.

Provision is to be made for relieving vacuum when the tanks are being pumped out and for this purpose a hole about 10 mm (0·375 in) in diameter in the bend of the air pipe or in a suitable position in the closing device will be acceptable.

406 In the case of all tanks which can be pumped up, either by the ship's pumps or by shore pumps through a filling main, the total cross-sectional area of the air pipes to each tank or of the overflow pipes where an overflow system is provided, is not to be less than 25 per cent greater than the effective area of the respective filling pipes.

Where tanks are fitted with cross flooding connections the air pipes are to be of adequate area for these connections. Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

In wire gauze diaphragms at air pipe openings, the area of the clear opening is not to be less than the cross-sectional area required for the pipe.

Air pipes are not to be less than 50 mm (2 in) bore.

407 The arrangement of the overflow system is to be such that in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through the overflow main.

Air and overflow pipes are to be arranged to be self-draining under normal conditions of trim.

408 Overflow pipes are to be fitted to oil fuel storage, settling and daily service tanks when the pressure head corresponding to the height of the air pipe is greater than that for which the tanks are suitable or when the sectional area of the air pipe is less than required by 406.

The pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes.

A sight glass is to be provided in the overflow pipe to indicate when the tanks are overflowing or, alternatively, an alarm device is to be provided to give warning either when the tanks are overflowing or when the oil reaches a predetermined level in the tanks.

409 Where overflows from tanks which are used for the alternative carriage of oil and water ballast are connected to an overflow system, arrangements are to be made to prevent water ballast overflowing into tanks containing oil (see also E 324).

410 Air and overflow pipes are to be of steel having a minimum thickness of 5 mm (0·19 in) or other approved material and thickness. Steel pipes slightly less in thickness may be accepted, provided they be suitably coated to prevent corrosion. Where not in contact with oil fuel or cargo oil, suitable protection may be provided by galvanizing the pipes on completion.

The portions of air and overflow pipes fitted above deck are to be of steel or other approved ductile material and of robust construction.

Where flanged connections are employed, heavy flanges with closely spaced bolts are to be fitted.

Sounding Pipes

411 Provision is to be made for sounding all tanks, and the bilges of those compartments which are not at all times readily accessible.

The soundings are to be taken as near the suction pipes as practicable.

412 Sounding pipes, including those for the double bottom tanks below the machinery spaces, should be led to positions above the bulkhead deck which are at all times accessible.

These pipes should be as straight as practicable, and if curved to suit the structure of the ship, the curvature must be sufficiently easy to permit the ready passage of the sounding rod or chain.

Nameplates are to be affixed to the upper ends of all sounding pipes.

413 In machinery spaces and tunnels where it is not always practicable to extend the sounding pipes as mentioned in 412, short sounding pipes extending to readily accessible positions above the platform may be fitted.

Short sounding pipes to oil fuel and lubricating oil tanks are to be fitted with cocks having parallel plugs with permanently attached handles so loaded that, on being released, they automatically close the cocks. As a further precaution against fire, such sounding pipes are to be located in positions as far removed as possible from any heated surface or electrical equipment and, where necessary, effective shielding is to be provided in way of such surfaces and/or equipment.

Short sounding pipes to tanks other than oil tanks are to be fitted with shut-off cocks or with screw caps attached to the pipes by chains.

In passenger ships, short sounding pipes are permissible only for sounding cofferdams and double bottom tanks situated in the machinery space and are in all cases to be fitted with self-closing cocks as described in the foregoing.

- 414 Tank sounding devices of approved type may be used in lieu of sounding pipes. These devices are to be tested, after fitting on board, to the satisfaction of the Surveyors.
- 415 If gauge glasses are used for indicating the level of liquid in tanks containing lubricating oil, oil fuel or other flammable liquid, the glasses are to be of heat-resisting quality adequately protected from mechanical damage and fitted with self-closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.
- 416 Sounding pipes to oil compartments are not to terminate within refrigerated cargo chambers or in the fan and battery rooms for these chambers, nor are these pipes to terminate in enclosed spaces from which access is provided to refrigerated cargo chambers or their fan and battery rooms, if it be practicable to avoid doing so.

Where these sounding pipes do terminate in such spaces they are to be fitted with self-closing cocks having parallel plugs.

- 417 Sounding pipes are not to be less than 32 mm (1·25 in) bore. All sounding pipes, whether for compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0°C (32°F) or below, are not to be less than 65 mm (2·5 in) bore.
- 418 All pipes, including scupper pipes, air pipes and sounding pipes which pass through chambers intended for the carriage or storage of refrigerated produce are to be well insulated.

Where such pipes pass through chambers intended for a temperature of 0°C (32°F) or below, they are also to be insulated from the steel structure except in positions where the temperature of the structure is mainly controlled by the external temperature and will normally be above freezing point. Pipes passing through a deck plate within the ship side insulation, where the deck is fully insulated below and has an insulation ribband on top, are to be attached to the deck plating.

In the case of pipes adjacent to the shell plating, metallic contact between the pipes and the shell plating or frames is to be arranged so far as practicable.

The air refreshing pipes to and from refrigerated compartments need not, however, be insulated from the steel work.

419 Sounding pipes are to be of steel having a minimum thickness of 4,5 mm (0.17 in) or other approved

material and thickness. Steel pipes slightly less in thickness may be accepted, provided they be suitably coated to prevent corrosion. Where not in contact with oil fuel or cargo oil, suitable protection may be provided by galvanizing the pipes on completion.

Where flanged connections are employed, heavy flanges with closely spaced bolts are to be fitted.

420 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

421 Elbow sounding pipes are not to be used for deep tanks unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids.

They may, however, be fitted to other tanks and may be used for sounding bilges, provided it is not practicable to lead them direct to the tanks or compartments.

The elbows are to be of heavy construction and adequately supported.

In passenger ships, elbow sounding pipes are not permissible.

Extract from Chapter D for reference

Air and Sounding Pipes

D 2911 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is not normally to be less than:—

On the freeboard deck ... 760 mm (30 in), On superstructure decks ... 450 mm (17.5 in).

These heights are to be measured above sheathing, where fitted.

Lower heights may be approved in cases where these are essential for the working of the ship, provided the design and arrangements are otherwise satisfactory.

- D 2912 All openings of air and sounding pipes are to be provided with permanently attached satisfactory means of closing to prevent the free entry of water.
- D 2913 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.
- D 2914 Air and sounding pipes are to be well protected in all spaces. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, fork lift trucks or similar items is a possibility.

PRESSURE PIPES

General

501 The requirements of this Section, unless otherwise specifically stated, are primarily intended for piping systems in which the design pressure is 7 kg/cm² (100 lb/in²) and over.

Copper and Copper Alloy Pipes

502 Copper and copper alloy pipes are to be seamless or of approved welded type.

Branches are to be provided by cast or stamped fittings, by pipe pressings, or by other approved fabrications.

503 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried. All brazing and welding is to be carried out to the satisfaction of the Surveyors.

504 The maximum working temperatures permitted for pipe and branch materials are indicated in Table E 5.1. Where it is proposed to use other copper alloys, particulars of chemical composition and mechanical properties at the working temperature including, if applicable, creep and rupture data, are to be submitted for consideration.

505 Where copper and copper alloy pipes are bent, they are to be made 10 per cent thicker than required by 506 to provide for thinning at the bend.

In no case is the radius of curvature at the centreline of the pipe to be less than twice the outside diameter of the pipe.

506 The minimum thickness of seamless copper and copper alloy pipes is to be determined by the following formula:—

$$T = \frac{PD}{2f} + 0.75 \; mm \left(T = \frac{PD}{2f} + 0.03 \; in \right) \label{eq:total_total_total}$$

where T = thickness, in mm (in),

P = design pressure, in kg/cm² (lb/in²), which in the case of feed pipes, is to be 1,25 times the boiler design pressure,

D = outside diameter, in mm (in),

f = allowable stress, in kg/cm² (lb/in²), from Table E 5.1. Intermediate values of stresses to be obtained by linear interpolation.

507 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to testing by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

Steel Pipes

508 Steel pipes for a design pressure exceeding 17,5 kg/cm² (250 lb/in²) or a temperature exceeding 220°C (428°F), and all feed pipes and pressure pipes conveying heated oil are to be manufactured and tested in accordance with the requirements of Q 7. Where it is proposed to use materials for pipes other than shown in Q 7, the information called for in 511 (a) is to be submitted for consideration.

509 Pipes other than those mentioned in 508 may be made and tested

(a) to the requirements of Q 7, or,

(b) in accordance with an approved national specification, except that forge butt welded pipes are not acceptable.

510 Pipes having forge butt welded longitudinal seams are not to be used for oil fuel systems, for heating coils in oil tanks, or for pressures exceeding 3,5 kg/cm² (50 lb/in²).

511 The thickness of steel pipes intended for steam, feed, air, oil fuel and other pressure services is to be determined by the formulæ in 512 and 513 and the following definitions are given in respect of the symbols used in the formulæ:—

(a) The allowable stress, f, is obtained from the material properties of the appropriate category, grade and tensile range of steel indicated in Q 7 and is to be taken as the lowest of the following values:—

$$f = \frac{E_t}{1,6} \qquad f = \frac{R_{20}}{2,7} \qquad f = \frac{S_R}{1,6}$$

where E_t = specified minimum lower yield stress or 0,2 per cent proof stress at the temperature under consideration,

R₂₀ = specified minimum tensile strength at room temperature,

S_R = average stress to produce rupture in 100 000 hours at the temperature under consideration.

In general, when determining the value of the allowable stress, f, the temperature of the pipeline is to be taken as the maximum temperature of the internal fluid, but in no case is to be less than 100°C (212°F). In the case of pipes for superheated steam the temperature is to be taken as the designed operating steam temperature for the pipeline provided the temperature at the superheater outlet is closely controlled. Where temperature fluctuations exceeding 14 degC (25 degF) above the designed temperature are to be expected in normal service the steam temperature to be used for determining the allowable stress is to be increased by the amount of this excess.

Values of the allowable stress, f, are shown in Tables E 5.2 and E 5.3. For intermediate temperatures, values of the allowable stress may be obtained by interpolation.

Where it is proposed to use, for high temperature service, alloy steels other than those stated in Q 7, particulars of the tube sizes, design conditions and appropriate national or proprietary material specifications are to be submitted for consideration.

Where the material does not conform to an established standard, particulars of the chemical composition, deoxidizing medium, heat treatment, mechanical properties and measured or estimated long-term stress to rupture data at the proposed operating temperature are to be submitted for the purpose of assessing a safe allowable stress.

(b) (i) The design pressure, P, for feed pipes is to be taken as 1,25 times the design pressure of the boiler, or the maximum pressure which can be developed in the feed line in normal service, whichever is the greater.

(ii) With water tube boiler installations the design pressure, P, is to be taken as the approved design pressure of the boiler for steam pipes between the boiler and integral superheater and as the pressure to which the superheater safety valves are set for the steam pipes leading from the superheater. Where the superheater safety valves are controlled by pilot valves operated from the saturated steam drum, then the design pressure for the steam pipes leading from the superheater is to be taken as the design pressure of the boiler.

Note. In installations where the boiler pressure, as controlled by the safety valve settings, is less than the design pressure of the boiler, it will be permissible for thicknesses of external steam and feed pipes to be based on the former.

TABLE E 5.1

Dine	Minimum tensile	0,5 per cent			58		Allowal	ole Stress	kg/em²				
Pipe Material	strength kg/mm ²	proof stress kg/mm ²	50°C	75°C	100°C	125°C	150°C	175°C	200°C	225°C	250°C	275°C	300°C
Copper	22	6	420	415	405	390	330	270	220	Cabana a	10. 200		
Aluminium Brass	33	13	705	700	-685	665	635	435	245		la co al	-01	
Copper Nickel 95/5 & 90/10	28	14	705	700	685	665	645	610	570	510	445	385	
Copper Nickel 70/30	40	14	845	820	775	740	700	675	650	625	600	575	550

or in British units:-

Pipe Material	Minimum tensile	0.5 per cent proof stress					Allowa	ble Stress	lb/in²				
Material	strength ton/in2	ton/in ²	50°C	75°C	100°C	125°C	150°C	175°C	200°C	225°C	250°C	275°C	300°C
Copper	14	4	5970	5910	5760	5550	4690	3840	3130				7
Aluminium Brass	21	8	10 030	9960	9740	9460	9040	6190	3490	T HAT			
Copper Nickel 95/5 & 90/10	18	9	10 030	9960	9740	9460	9180	8680	8110	7260	6340	5480	
Copper Nickel 70/30	25.5	9	12 030	11 680	11 030	10 530	9960	9600	9250	8890	8540	8180	7820

- (c) The thickness, T, determined by the formula in 512 is the minimum thickness for straight pipes and the thickness, T_b, determined by the formulæ in 513 is the minimum thickness of a straight pipe from which a pipe bend is to be made. In both cases provision must be made for any minus tolerance to which the pipes may be manufactured.
- (d) The outside diameter, D, of the pipe may be subject to manufacturing tolerances but these tolerances are not to be used in the evaluation of formulæ.

512 The minimum thickness of straight steel pipes intended for the services referred to in 511 is to be determined by the following formula:—

$$T = \frac{C P D}{2f + P}$$

where T = minimum thickness, in mm (in). (See Notes 1 and 2),

P = design pressure, in kg/cm² (lb/in²),

D = outside diameter of pipe, in mm (in),

f = allowable stress, in kg/cm² (lb/in²), from Tables E 5.2 or E 5.3, the symbols being as defined in 511.

C = 1,4 for oil fuel pipes and steam heating pipes in contact with oil,

= 1,0 for all other pipes.

For pipes intended for the services permitted by 509 and made and tested in accordance with 509 (b) the allowable stress is to be taken as 80 per cent of the values given in Table E 5.3 for the appropriate specified minimum tensile strength.

The formula does not provide for adverse corrosion conditions. In the case of steam and feed pipes over 25 mm (1 in) bore intended for low pressure boilers having design pressures up to $17,5 \text{ kg/cm}^2$ (250 lb/in²), and for any boilers with open feed systems, these pipes are to be made 1 mm (0.04 in) thicker than required by the formula.

Notes.

- 1. The value of T is the minimum thickness for straight pipes and provision must be made for any minus tolerance to which the pipes may be manufactured. (See Q 707 (c) for tolerance on wall thickness.)
- 2. Practical considerations such as manufacture, fabrication and robustness may make it necessary for pipes thicker than this minimum to be used. In such cases, the nominal pipe thickness should in general, not be less than shown in Table E 5.4 for the appropriate standard pipe size.

- 513 The minimum thickness, $T_{\rm b}$, of a straight steel pipe to be used for a pipe bent to a radius in accordance with Table E 5.5 is to be determined by the formulæ below, except where it can be demonstrated that the use of a thickness less than $T_{\rm b}$ would not reduce the thickness below T at any point after bending. (See Notes 1 and 2.)
 - (i) For pipes bent to the radii specified in Table E 5.5 Columns 2 and 4:—

$$T_b = 1,125 \text{ T}$$
 (1)

(ii) For pipes exceeding 220 mm (8.625 in) outside diameter, and where T is 32 mm (1.25 in) or more, bent to the radii specified in Table E 5.5 Column 5:—

$$T_{\rm b} = 1.1 \text{ T}$$
 (2)

NOTES.

- 1. The value of T_b is the minimum thickness and provision must be made for any minus tolerance to which the pipes may be manufactured. (See Q 707 (c) for tolerance on wall thickness.)
- 2. Practical considerations such as manufacture, fabrication and robustness may make it necessary for pipes thicker than this minimum to be used. In such cases, the nominal thickness of a straight steel pipe to be used for a pipe bend should in general, not be less than shown in Table E 5.4.
- 514 Any proposal to bend pipes to smaller radii than shown in Table E 5.5 will be the subject of special consideration and further allowance is to be made for thinning at the outside of the bend, except where it can be demonstrated that the use of a thickness $T_{\rm b}$ would not reduce the thickness below T at any point after bending.

There is a minimum thickness for each size of pipe dependent on bending procedure below which the allowance for thinning will be exceeded, and in such cases the radius given in Table E 5.5 is to be increased where necessary to ensure that the thickness is not below T at any point after bending.

Pipe Joints

515 Joints in pressure pipe lines may be made by bolted flanges or by butt welds between pipes or between pipes and valve chests, or other fittings, but with the latter system it is desirable that a few flanged joints be provided at suitable positions to facilitate installation, cold "pull up" and inspection at periodical surveys.

Where pressure pipe lines are assembled and butt welded in place the piping is to be arranged well clear of adjacent structures, to permit sufficient access for preheating, welding, heat treatment and examination of the joints.

TABLE E 5.2

Grade of	Yield Stress	Tensile Strength					A	llowable	Stress	kg/cm ²	(see E 51	1)				
Steel	kg/mm ²	kg/mm ²	100°C	150°C	200°C	250°C	300°C	350°C	390°C	400°C	410°C	420°C	430°C	440°C	450°C	46
Carbon	21,3	35–47	1165	1150	1125	1060	930	825	765	750	670	590	520	455	405	35
Carbon	25,2	42-54	1280	1260	1210	1140	1005	915	885	780	670	590	520	455	405	35
1 Cr−½ Mo	23,6	42-63	1420	1375	1325	1190	1045	945	930	930	925	920	915	910	905	90
2 ¹ / ₄ Cr-1 Mo (Note 1)	23,6	42–57	1245	1135	975	945	915	875	850	845	840	835	830	825	825	82
2½ Cr-1 Mo (Note 2)	26,8	50–70	1610	1595	1560	1490	1440	1375	1320	1305	1290	1280	1270	1260	1250	124
Cr-1 Mo-1 V	30,0	47-62	1610	1595	1560	1490	1440	1375	1320	1305	1290	1280	1270	1260	1250	124

or in British units:-

Grade of	Yield Stress	Tensile Strength ton/in ²	man na				1	Allowabl	e Stress	lb/in² (see E 51	1)				
Steel	ton/in ²	ton/in²	100°C	150°C	200°C	250°C	300°C	350°C	390°C	400°C	410°C	420°C	430°C	440°C	450°C	46
Carbon	13.5	22 · 2–29 · 8	16 580	16 370	16 000	15 090	13 220	11 730	10 890	10 680	9540	8390	7400	6470	5760	498
Carbon	16.0	26 · 7 – 34 · 3	18 210	17 920	17 210	16 210	14 300	13 020	12 600	11 100	9540	8390	7400	6470	5760	498
1 Cr-½ Mo	15.0	26 · 7 – 40 · 0	20 200	19 560	18 850	16 920	14 870	13 440	13 220	13 220	13 170	13 090	13 010	12 970	12 880	12
2½ Cr-1 Mo (Note 1)	15.0	26 · 7 – 36 · 2	17 710	16 150	13 880	13 440	13 020	12 450	12 090	12 020	11 950	11 880	11 800	11 730	11 730	11
2½ Cr-1 Mo (Note 2)	17.0	31 - 7 - 44 - 4	22 900	22 680	22 200	21 200	20 480	19 560	18 790	18 580	18 360	18 210	18 080	17 920	17 790	17
Cr-½ Mo-¼ V	19.0	29 · 8 – 39 · 4	22 900	22 680	22 200	21 200	20 480	19 560	18 790	18 580	18 360	18 210	18 080	17 920	17 790	17

Notes: 1. Annealed condition.

ATEGORY I MATERIAL

				A	llowable	Stress	${\rm kg/cm^2}$	(see E 51	1)					Tensile Strength	Yield Stress kg/mm ²	Grade of
470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580C°	590°C	600°C	Strength kg/mm ²	kg/mm ²	Steel
310	275				212	44	ene a	10/0	Oct	hris.		(Lox)		35–47	21,3	Carbon
310	275	ALIE.				an					0.011			42–54	25,2	Carbon
895	895	890	885	775	635	500	395	310	255	205	otte		200-0	42–63	23,6	1 Cr-½ Mo
820	815	810	800	795	785	720	620	530	455	385	325	275	240	42–57	23,6	2½ Cr-1 Mo (Note 1)
230	1215	1200	1070	945	825	720	620	530	455	385	325	275	240	50-70	26,8	2½ Cr-1 Mo (Note 2)
230	1215	1200	1180	1035	885	755	635	550	460	405	345			47-62	30,0	½ Cr-½ Mo-½ V

					Allowabl	le Stress	lb/in² (see E 51	1)					Tensile Strength	Yield Stress	Grade of
470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C	Strength ton/in ²	ton/in2	Steel
4410	3910	i i i					000	ugill			aru.	Mill	4 10-4	22 · 2-29 · 8	13.5	Carbon
4410	3910		14547	acr				uide;		62 CL	on it		1 12-1	26 · 7 – 34 · 3	16.0	Carbon
12 730	12 730	12 660	12 590	11 030	9040	7110	5620	4410	3630	2920		ato br	E-10-1	26 · 7 – 40 · 0	15.0	1 Cr-1 Mo
11 670	11 600	11 510	11 390	11 310	11 170	10 240	8820	7540	6470	5480	4620	3910	3420	26 · 7 – 36 · 2	15.0	2¼ Cr-1 Мо (Nоте 1)
17 500	17 290	17 080	15 250	13 440	11 730	10 240	8820	7540	6470	5480	4620	3910	3420	31 · 7 – 44 · 4	17.0	2½ Cr-1 Mo (Note 2)
17 500	17 290	17 080	16 790	14 720	12 600	10 740	9040	7830	6550	5760	4910			29 · 8 – 39 · 4	19.0	½ Cr-½ Mo-¼ V

Notes: 1. Annealed condition.

Grade of	Yield	Tensile					Allowa	able Stre	ess kg/c	m² (see I	E 511)				
Steel	Stress kg/mm²	Strength kg/mm ²	100°C	150°C	200°C	250°C	300°C	350°C	400°C	410°C	420°C	430°C	440°C	450°C	4604
Carbon	16,5	33-45	785	755	730	665	575	455	450	445	445	445	445	405	35
Carbon	17,8	35-47	850	830	815	730	635	525	515	515	515	515	455	405	35
Carbon	21,5	42–54	1125	1100	1080	990	885	785	770	670	590	520	455	405	35
1 Cr -1 Mo	22,5	42-63	1215	1170	1130	1010	885	800	785	785	780	775	775	770	76
2½ Cr-1 Mo (Note 1)	21,5	42–57	1060	960	830	800	775	740	720	715	715	710	705	700	69
2½ Cr-1 Mo (Note 2)	25,0	50-70	1365	1355	1330	1270	1215	1170	1105	1100	1090	1080	1070	1060	105
Cr-1 Mo-1 V	28,0	47-62	1365	1355	1330	1270	1215	1170	1105	1100	1090	1080	1070	1060	105

or in British units :-

TABLE E 5.3

Grade of	Yield	Tensile					Allow	able St	ress lb/i	n² (see E	511)				
Steel	Stress ton/in ²	Tensile Strength ton/in ²	100°C	150°C	300°C	250°C	300°C	350°C	400°C	410°C	420°C	430°C	440°C	450°C	460
Carbon	10.5	21 · 0 – 28 · 6	11 170	10 740	10 380	9460	8190	6470	6400	6340	6340	6340	6340	5760	498
Carbon	11.3	22 · 2-29 · 6	12 090	11 810	11 590	10 380	9040	7460	7330	7330	7330	7330	6470	5760	498
Carbon	13.7	26 · 7 – 34 · 3	16 000	15 650	15 370	14 090	12 600	11 170	10 950	9540	8390	7400	6470	5760	498
1 Cr−½ Mo	14.3	26 · 7 – 40 · 0	17 290	16 630	16 080	14 380	12 600	11 380	11 170	11 170	11 100	11 020	11 020	10 950	108
2¼ Cr-1 Mo (Note 1)	13.7	26 · 7 – 36 · 2	15 080	13 670	11 810	11 380	11 020	10 530	10 240	10 180	10 180	10 100	10 030	9960	989
2½ Cr-1 Mo (Note 2)	15.9	31 · 7 – 44 · 4	19 410	19 280	18 920	18 070	17 280	16 640	15 710	15 660	15 500	15 370	15 220	15 080	15
½ Cr-½ Mo-¼V	17.8	29 · 8 – 39 · 4	19 410	19 280	18 920	18 070	17 280	16 640	15 710	15 660	15 500	15 370	15 220	15 080	15

Notes: 1. Annealed condition.

CATEGORY II MATERIAL

				Al	lowable	Stress 1	kg/cm² (see E 51	1)					Tensile	Yield	Grade of
70°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C	Strength kg/mm ²	Stress kg/mm ²	Steel
310	275													33-45	16,5	Carbon
310	275		140-51			2.1		P411-0					1006-1	35–47	17,8	Carbon
310	275	240	205											42–54	21,5	Carbon
60	760	755	755	750	635	500	395	310	255	205	1,00 1,63 2,172		(SE) -1	42–63	22,5	1 Cr−½ Mo
90	690	685	680	680	675	665	620	530	455	385	325	275	240	42–57	21,5	2¼ Cr-1 Mo (Note 1)
45	1035	1020	1005	945	825	720	620	530	455	385	325	275	240	50-70	25,0	2½ Cr-1 Mo (Note 2)
45	1035	1020	1005	990	885	755	635	550	460	405	345			47-62	28,0	½ Cr-½ Mo-¼ V

ATEGORY II MATERIAL

					Allowabl	e Stress	lb/in² (see E 51	1)					Tensile	Yield	Grade of
70°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C	Strength ton/in ²	Yield Stress ton/in ²	Steel
110	3910													21 · 0-28 · 6	10.5	Carbon
10	3910						MILE.						di na	22 · 2-29 · 6	11 · 3	Carbon
10	3910	3420	2920	02 E	6							9	101	26 · 7 – 34 · 3	13.7	Carbon
810	10 810	10 740	10 740	10 680	9040	7110	5620	4410	3630	2920			101	26 · 7 – 40 · 0	14.3	1 Cr-½ Mo
10	9810	9750	9670	9670	9600	9460	8820	7540	6470	5480	4620	3910	3420	26 · 7 – 36 · 2	13.7	2¼ Cr-1 Mo (Note 1)
880	14 720	14 520	14 300	13 440	11 730	10 240	8820	7540	6470	5480	4620	3910	3420	31 · 7-44 · 4	15.9	2¼ Cr-1 Mo (Note 2)
880	14 720	14 520	14 300	14 090	12 600	10 740	9040	7830	6550	5760	4910		VIII	29 · 8 – 39 · 4	17.8	½ Cr-½ Mo-¼V

Notes: 1. Annealed condition. 2. Normalized and tempered condition.

TABLE E 5.4

	STANDARD PIPE SIZES	MINIMUM O				
0,011	exceeding	Not ex	rceeding	NOMINAL THICKNESS		
mm	(in)	mm	(in)	mm	(in)	
- 11	71-65	10,2	(0.406)	1,6	(0.064)	
10,2	(0.406)	17,2	(0.688)	- 1,8	(0.072)	
17,2	(0.688)	26,9	(1.063)	2,0	(0.08)	
26,9	(1.063)	33,7	(1.344)	2,3	(0.092)	
33,7	(1.344)	54,0	(2.125)	2,6	(0.104)	
54,0	(2·125)	76,1	(3.0)	2,9	(0.116)	
76,1	(3.0)	88,9	(3.5)	3,2	(0.128)	
88,9	(3.5)	114,3	(4.5)	3,6	(0.144)	
114,3	(4.5)	139,7	(5.5)	4,0	(0.160)	
139,7	(5.5)	168,3	(6.625)	4,5	(0.176)	
168,3	(6.625)	193,7	(7.625)	5,4	(0.212)	
193,7	(7 · 625)	219,1	(8 · 625)	5,9	(0.232)	
219,1	(8.625)	273,0	(10.75)	6,3	(0.250)	
273,0	(10.75)	323,9	(12.75)	7,1	(0.280)	
323,9	(12.75)	368,0	(14.5)	8,0	(0.312)	
368,0	(14.5)	419,0	(16.5)	8,8	(0.344)	

TABLE E 5.5

Minimum bending radii for steel pipes of thickness determined by the formulæ in E 513.

	1		2	200	3		4		5
Outside Diameter				Outside Diameter		Radii measured to centreline of pipe			
						T _b = 1,125T All thicknesses		T _b = 1,1T T _b = 35 mm (1.375 in or above	
mm	(in)	mm	(in)	mm	(in)	mm	(in)	mm	(in)
26,9 33,7 42,4 48,3 60,3 76,1 88,9 101,6 114,3 127,0	$\begin{array}{c} (1 \cdot 063) \\ (1 \cdot 344) \\ (1 \cdot 688) \\ (1 \cdot 906) \\ (2 \cdot 375) \\ (3 \cdot 0) \\ (3 \cdot 5) \\ (4 \cdot 0) \\ (4 \cdot 5) \\ (5 \cdot 0) \end{array}$	63 76 101 114 152 190 228 267 305 355	$\begin{array}{c} (2 \cdot 5) \\ (3 \cdot 0) \\ (4 \cdot 0) \\ (4 \cdot 5) \\ (6 \cdot 0) \\ (7 \cdot 5) \\ (9 \cdot 0) \\ (10 \cdot 5) \\ (12 \cdot 0) \\ (14 \cdot 0) \end{array}$	244,5 273,0 298,5 323,9 355,6 381,0 406,4 457,2	(9·625) (10·75) (11·75) (12·75) (14·0) (15·0) (16·0) (18·0)	810 1020 1120 1220 1500 1600 1730 2030	(32) (40) (44) (48) (59) (63) (68) (80)	1140 1270 1400 1520 1780 1900 2030 2280	(45) (50) (55) (60) (70) (75) (80) (90)
139,7 152,4 165,1 168,3 177,8 193,7 219,1	$(5 \cdot 5)$ $(6 \cdot 0)$ $(6 \cdot 5)$ $(6 \cdot 625)$ $(7 \cdot 0)$ $(7 \cdot 625)$ $(8 \cdot 625)$	380 430 460 460 580 630 710	(15·0) (17·0) (18·0) (18·0) (23·0) (25·0) (28·0)		Affic) - OMF		01011001	IL cohel	

When hydraulic testing the pipe lines, the test pressure P_T is to be in accordance with 523 or twice the design pressure, whichever is the lesser; terminal valves should be capable of withstanding the same test pressure when closed. In the supporting and securing arrangements for the pipe lines, provision is to be made for these hydraulic test conditions.

Steel Pipe Flanges

516 Flanges are to be weldless and of material suitable for the design temperature. They may be attached to pipes by screwing and expanding or by welding depending upon the pressures and temperatures for which the various types are acceptable as indicated in Table E 5.6. Acceptable methods of attachment are illustrated in Fig. E 5.1.

If backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of good quality mild steel having a sulphur content not greater than 0,06 per cent. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 150 mm (6 in) outside diameter. Flange types (c) and (e) are unsuitable for pipes under 75 mm (3 in) bore.

TABLE E 5.6

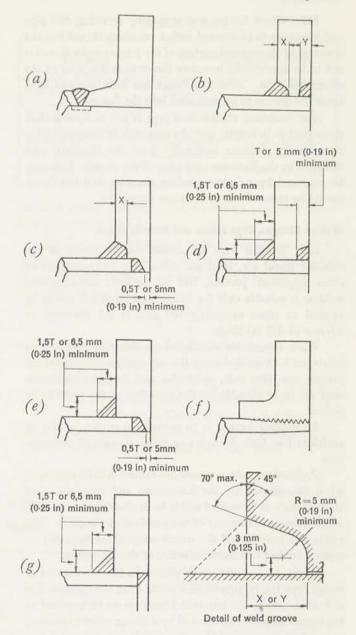
	Service and Rating							
Type of Flange Attachment	Feed, A	ir, Oil Fuel ther fluids	Steam					
	Pressure kg/em² (lb/in²)	Temperature °C (°F)	Pressure kg/cm ² (lb/in ²)	Temperature °C (°F)				
(a), (b) & (c)	All Co	onditions	All Conditions					
(d) & (e)	52,5 (750)		38,5 (550)	400				
(f)	42 (600)	260 (500)	31,5 (450)	(750)				
(g)	17,5 (250)		17,5 (250)	260 (500)				

Alternative methods of flange attachment and other types of pipe joints may be accepted provided details are submitted for special consideration.

For flange types (b) and (c), dimension X is to be taken as T for carbon steel and 2T for alloy steel pipes but is not to be less than shown in the Table associated with Fig. E 5.1.

For flange type (b), dimension Y is to be taken as T for carbon steel and 2T for alloy steel pipes but is not to be less than 5 mm (0·19 in).

T is to be taken as the rule thickness of the pipe.



Pipe Bore	Dimension X Minimum		
13 mm and 19 mm	6,5		
(0·5 in and 0·75 in)	(0·25 in)		
25 mm to 38 mm	8,0 mm		
(1 in to 1 · 5 in)	(0·3125 in)		
50 mm and over	9,5 mm		
(2 in and over)	(0·375 in)		

Fig. E 5.1 Acceptable Methods of Attaching Flanges to Steel Pipes

517 Where flanges are secured by screwing, the pipe and flange are to be screwed with a vanishing thread and the diameter of the screwed portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unscrewed pipe. After the flange has been screwed hard home the pipe is to be expanded into the flange.

The vanishing thread on a pipe is not to be less than three pitches in length, and the diameter at the root of the thread is to increase uniformly from the standard root diameter to the diameter at the top of the thread. This may be produced by suitably grinding the dies, and the flange should be tapered out to the same formation.

Welded Flanges, Pipe Joints and Branch Pieces

518 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to pipes exceeding 100 mm (4 in) diameter or 9.5 mm (0.375 in) thick.

When flanges are attached by welding or pipe-to-pipe joints are butt welded using the oxy-acetylene or metal arc process the filler rods, electrodes and fusible root inserts used are to be suitable for the materials of the parts to be joined.

All welding work is to be carried out in shop or ship in positions free from draughts or rapid changes of temperature.

Preheating under temperature control is to be employed when necessitated by the dimensions and composition of the materials to be welded and is to be effected by a method which ensures uniformity of temperature at the joint. The method of heating and the means adopted for temperature control are to be to the satisfaction of the Surveyors.

Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

Butt welds may be reinforced externally by additional runs of weld metal. All welds in high pressure and high temperature pipe lines are to have a smooth surface finish and even contour; if necessary they are to be made smooth by grinding. No undercutting of the pipe at the edges of the weld is acceptable. 519 Branches may be attached to pressure pipes by means of welding provided the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively the thicknesses of pipe and branch are to be increased to maintain the strength of the pipe.

These requirements also apply to fabricated branch pieces.

520 The welding procedure proposed for the attachment of flanges, valve chests and other fittings to pipes, pipes-to-pipes and the fabrication of branch pieces, whether in carbon or alloy steel, is to be approved by the Surveyors in the first instance before work is commenced. For this purpose representative specimens of such parts will be required for examination and test.

The assembly for the weld procedure test and the welding technique should simulate the conditions under which the work is to be done on the installation. Test welds are to be examined for defects by the appropriate method specified in 521. The test welds are then to be sectioned at positions selected by the Surveyor, one surface of each section being prepared, etched and examined for defects in the weld and heat affected zones. In the case of pipes or branch pieces of alloy steel, mechanical tests and tests to destruction may also be required to demonstrate that the joints are of adequate strength. Check tests of the quality of the work of the welders are to be carried out periodically at the Surveyor's discretion.

521 All welds attaching flanges and branches to alloy steel pipes of 76 mm (3 in) bore and over are to be examined to ensure as far as possible that the welds are satisfactory. These examinations are to be carried out by radiography where practicable or by other approved methods.

All butt welded joints in steam pipe lines, of 76 mm (3 in) bore and over, when made of carbon steel for the design conditions referred to in 508, or of low alloy steel, are to be examined by radiographic or other approved methods. The techniques are to be applied to the satisfaction of the Surveyor and are to be of a sensitivity which is suitable to disclose detrimental defects. For radiographic examinations and required standards of sensitivity, see J 420 to J 423.

Fillet welds in fabricated branch pieces are to be examined by magnetic crack detection methods.

Small detrimental defects, if found, are to be cut out and the seam re-welded and re-examined. In the case of major defects the joint is to be re-machined and completely re-welded.

Heat Treatment of Steel Pipes and Branch Pieces

522 Carbon steel pipes and fabricated branch pieces having a thickness of 19 mm (0.75 in) and over are to be

stress relieved on completion of welding. Where oxyacetylene welding has been employed, however, all the pipes and branch pieces are to be normalized on completion of welding in accordance with the requirements of Table Q 7.2.

All alloy steel pipes and fabricated branch pieces are to be carefully and suitably heat treated in accordance with the requirements of Table Q 7.2 after:—

- (a) oxy-actylene welding, or
- (b) being heated for forming or bending operations, or
- (c) being cold bent to a radius measured at the centreline of the pipe of less than 3,5 D.

After electric arc welding all alloy steel pipes and branch pieces are to be given a stress relieving heat treatment.

Suitable temperatures for stress relieving carbon and alloy steel pipes and branch pieces are given in Table E 5.7 and should be maintained for one hour per 25 mm (1 in) of wall thickness.

Hydraulic Test Pressures

523 (a) All copper and copper alloy main steam and feed pipes are, on completion, to be tested by hydraulic pressure to not less than twice the design pressure as defined in 506. Other copper and copper alloy pipes are to be

TABLE E 5.7

Pipe Steel	Temperature limits for Stress Relieving			
Carbon	580-620°C	(1080–1150°F)		
1 Cr-½ Mo	620–670°C	(1150–1240°F)		
2½ Cr-1 Mo	650-690°C	(1200–1270°F)		
½ Cr−½ Mo−¼V	650-710°C	(1200–1310°F)		

similarly tested when intended for design pressures above 10,5 kg/cm² (150 lb/in²).

(b) All steel pressure pipes, with the exception of those stated in (c) below, are on completion to be tested by hydraulic pressure to a pressure P_T determined by the following formula:—

$$P_T = \frac{KP}{2f}$$

where $P_T = \text{test pressure}$, in kg/cm² (lb/in²),

P = design pressure, in kg/cm² (lb/in²),

f = allowable stress, in kg/cm² (lb/in²), at the design temperature, determined by 511 (a) and shown in Tables E 5.2 and E 5.3,

K = a constant, depending on the pipe material, as indicated in Tables E 5.8 and E 5.9.

TABLE E 5.8

Category I Material

Grade of Steel	Yield Stress		Tensile Strength		Constant K	
	kg/mm ²	(ton/in2)	kg/mm ²	(ton/in2)	Metrio	(British)
Carbon	21,3	(13.5)	35–47	(22 · 2 – 29 · 8)	3160	(45 000)
Carbon	25,2	(16.0)	42-54	(26 · 7 – 34 · 3)	3790	(54 000)
1 Cr-1 Mo	23,6	(15.0)	42-63	(26 · 7-40 · 0)	3510	(50 000)
2½ Cr-1 Mo (Note 1)	23,6	(15.0)	42-57	(26 · 7 – 36 · 2)	3510	(50 000)
2½ Cr-1 Mo (Note 2)	26,8	(17.0)	50-70	(31 · 7-44 · 4)	4000	(57 000)
½ Cr−½ Mo−4V	30,0	(19.0)	47-62	(29 · 8 – 39 · 4)	4490	(64 000)

Notes. 1. Annealed condition.

TABLE E 5.9 Category II Material

Grade of	Yield Stress		Tensile Strength		Constant K		
Grade of Steel	kg/mm ² (ton/in ²)		kg/mm ² (ton/in ²)		Metric	(British)	
Carbon	16,5	(10.5)	33-45	(21 · 0 – 28 · 6)	2600 -	(37 000)	
Carbon	17,8	(11.3)	35-47	(22 · 2 – 29 · 8)	2670	(38 000)	
Carbon	21,5	(13.7)	42-54	(26 · 7-34 · 3)	3230	(46 000)	
1 Cr-½ Mo	22,5	(14.3)	42-63	(26 · 7 – 40 · 0)	3370	(48 000)	
21 Cr-1 Mo (Note 1)	21,5	(13.7)	42–57	(26 · 7 – 36 · 2)	3230	(46 000)	
2½ Cr-1 Mo (NOTE 2)	25,0	(15.9)	50-70	(31 · 7-44 · 4)	3720	(53 000)	
1 Cr-1 Mo-1V	28,0	(17.8)	47-62	(29 · 8 – 39 · 4)	4210	(60 000)	

Notes. 1. Annealed condition.

2. Normalized and tempered condition.

If the individual pipes are assembled and the joints butt welded in place, an additional hydraulic test to a pressure P_T, as indicated above, or to twice the design pressure, whichever is the lesser, is to be applied to the erected pipe line.

(c) Completed oil fuel pipes and heating coil systems, after fitting on board, are to be tested to twice the design pressure (See E 310, E 312 and E 335).

Cast Iron Heating Pipes

524 Where it is desired to use pressure pipes of cast iron, details are to be submitted.

Section 6

STEAM PIPE RANGES

Provision for Expansion

601 In all steam pipe ranges provision is to be made for expansion and contraction to take place without unduly straining the pipes.

Where corrugated pipes are used, particulars are to be submitted.

Drainage

602 The slope of the pipes and the number and position of the drain valves or cocks are to be such that

water can be efficiently drained from any portion of the steam pipe range when the ship is in normal trim and is either upright or has a list up to 5 degrees.

Arrangements are to be made for ready access to the drain valves or cocks.

Pipes in way of Holds

spaces which may be used for cargo, but where it is impracticable to avoid this arrangement, plans are to be submitted for consideration. The pipes are to be efficiently secured and insulated and well protected from mechanical damage. Pipe joints are to be as few as practicable and preferably butt welded. After fitting in place, the pipes are to be tested by hydraulic pressure to a pressure P_T, determined in accordance with E 523.

If these pipes are led through shaft tunnels, pipe tunnels in way of cargo holds or through duct keels, they are to be efficiently secured and insulated.

Reduced Pressure Lines

604 Pipe lines which are situated on the low pressure side of reducing valves and which are not designed to withstand the full pressure at the source of supply are to be fitted with pressure gauges and with relief valves having sufficient discharge capacity to protect the piping against excessive pressure.

Valves and Fittings

605 Valves and fittings intended either for steam pressures above 10,5 kg/cm² (150 lb/in²) or temperatures above 218°C (425°F) are to be of steel, carbon or low alloy, or other approved material suitable for the working temperature.

Castings of bronze, iron and carbon steel may be used within the following limits of temperature and pressure:—

 $\begin{array}{lll} {\rm Bronze} & 218^{\circ}{\rm C}\; 10,5\; {\rm kg/cm^2}\; (425^{\circ}{\rm F}\; 150\; {\rm lb/in^2}) \\ {\rm Iron} & 232^{\circ}{\rm C}\; 10,5\; {\rm kg/cm^2}\; (450^{\circ}{\rm F}\; 150\; {\rm lb/in^2}) \\ {\rm Carbon\; Steel} & 454^{\circ}{\rm C}\; (850^{\circ}{\rm F})\; {\rm all\; pressures}. \end{array}$

Hydraulic Test Pressure

606 All main steam and feed valves and fittings are to be tested by hydraulic pressure to not less than twice the working pressure as defined in E 506 and E 512. Other valves and fittings are to be similarly tested when intended for working pressures above 10,5 kg/cm² (150 lb/in²).

For the testing of boiler mountings, see J 626 and J 639.

Steam for Fire Extinguishing in Cargo Holds

607 Where steam is used for fire extinguishing in cargo holds, provision is to be made to prevent damage to cargo by leakage of steam or by drip.

Details of the proposed precautionary measures are to be submitted.

Section 7

BOILER FEED WATER SYSTEMS

Feed Pumps

701 Two separate means of feed are to be provided for all main and auxiliary boilers which are required for essential services, with the exception of boilers in which steam is generated exclusively by exhaust gases or steam, where one means of feed will be accepted provided an alternative steam supply is available.

702 Two or more feed pumps are to be provided of sufficient capacity to supply the boilers under full load conditions with any one pump out of action.

703 Feed pumps may be worked from the main engines or may be independently driven but at least one of the pumps required in 702 is to be independently driven.

704 In twin screw ships in which there is only one independent feed pump each main engine is to be fitted

with a feed pump. Where all the feed pumps are independently driven, the pumps are to be connected to deal with the condensate from both engines or from either engine.

705 Independent feed pumps required for feeding the main boilers are to be fitted with automatic regulators for controlling their output.

706 Where main-engine driven feed pumps are fitted and there is only one independent feed pump, a harbour feed pump or an injector is to be fitted to provide the second means of feed to the boilers which are in use when the main engines are not working.

707 Feed pumps are to be provided with valves or cocks interposed between the pumps and the suction and the discharge pipes so that any pump may be opened up for overhaul while the others continue in operation.

Sea Suctions

708 One of the independent feed pumps is to be provided with an emergency suction to the sea, except in the cases mentioned in 709.

Suctions are also to be provided from this pump to the hotwell or condenser, unless suitable stand-by connections have already been provided for this purpose.

709 The sea suction to a feed pump may be omitted if large reserve feed tanks are provided and an evaporator of adequate capacity is fitted.

Reserve Feed Water

710 All ships fitted with boilers are to be provided with storage space for reserve feed water, the structural and piping arrangements being such that this water cannot be contaminated by oil or oily water. See D 939, D 1923 and D 1928 for structural arrangements.

General Service Pump

711 An auxiliary independent feed pump may be used for general service, provided it is not connected to tanks containing oil fuel or cargo oil or to tanks, cofferdams and bilges containing oily water.

The valves on the suction pipes from the hotwell or condenser and the feed drain tank or filter are to be of nonreturn type.

Filters

712 Where superheated steam is used in main or auxiliary engines of reciprocating type, filters are to be fitted to provide for the continuous filtration of the boiler feed water.

713 Where a direct contact heater is supplied with exhaust steam from engines of reciprocating type, the feed water from the heater is to be led through the filters required by 712 or through additional filters arranged to provide for continuous filtration.

Cross-references

714 For materials, working pressure and test pressure of feed pipes, see E 501 to E 523.

For feed water level regulators for water tube boilers, see J 636.

Section 8

ENGINE COOLING WATER SYSTEMS

Main Supply

801 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

Alternative Supply

802 Provision is also to be made for a separate emergency supply of cooling water from a suitable pump.

When selecting a pump for this purpose, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed and, when necessary, condenser doors, water boxes, etc., are to be protected by an approved device against inadvertent over-pressure. See H 838 for the hydraulic test pressure which condensers are required to withstand.

Sea Inlets

803 Not less than two sea inlets are to be provided for the pumps supplying the salt water cooling system, one for the main pump and one for the stand-by pump. Alternatively, the sea inlets may be connected to a suction line available to main and stand-by pumps.

These inlets are to be low inlets and one of them may be the ballast pump or general service pump sea inlet.

Stand-by Fresh Water Pump

804 Where fresh water cooling is employed, a stand-by fresh water pump need not be fitted if there be suitable emergency connections from a salt water system.

Cooling Water Supply to Auxiliaries

805 Where each auxiliary is fitted with a cooling water pump, stand-by means of cooling need not be provided. Where, however, a group of auxiliaries is supplied with cooling water from a common system, a stand-by cooling water pump is to be provided for this system. This pump may be a suitable general service pump.

The auxiliary cooling water pumps are to be connected to not less than two sea inlets, preferably one on each side of the ship.

Strainers

806 Where sea water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

Relief Valves

807 Cooling water pumps worked from the main engines are to be provided with relief valves on the pump discharge.

Copper and Copper Alloy Piping Systems

808 When non-ferrous pipes are proposed for fresh and sea water piping systems, details of the materials and the duty for which they are intended may be submitted to the Society for approval.

In the selection of components for sea water piping systems, care should be taken to avoid metal combinations which may lead to galvanic corrosion in service.

See Chapter R(D) for Guidance Notes on Metal Pipes for Water Services.

Section 9

LUBRICATING OIL SYSTEMS

Pumps

901 In ships of unrestricted class in which the lubricating oil for the main engines (steam engines, oil engines, turbines or electric propelling motors), is circulated under pressure, a stand-by lubricating oil pump is to be provided where the following conditions apply:—

- (a) The lubricating oil pump is independently driven and the total output of the main engines exceeds 500 bhp.
- (b) One main engine with a built-in lubricating oil pump is fitted and the output of the engine exceeds 500 bhp.

(c) Two or more main engines each with a built-in lubricating oil pump are fitted and the output of each engine exceeds 500 bhp.

The stand-by pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use but where this is not convenient in the case of high speed oil engines with built-in pumps, a complete spare pump may be accepted for installation of type (c).

Similar provision is to be made where separate lubricating oil systems are employed for piston cooling, the operation of reverse reduction gears, oil operated couplings and controllable pitch propellers, unless approved alternative arrangements are provided.

902 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

Control of Pumps

903 The power supply to all independently driven pumps, delivering oil to main propulsion machinery for bearing lubrication and piston cooling is to be capable of being stopped from a position which will always be accessible in the case of a fire taking place in the compartment in which they are situated, as well as from the compartment itself.

Alarms

904 All main and auxiliary engines and turbines intended for essential services are to be provided with means for indicating the lubricating oil pressure supply to them. Where such engines and turbines are of more than 50 horse power, audible and visible alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

Emergency Supply for Propulsion Turbines and Propulsion Turbo-Generators

905 A suitable emergency supply of lubricating oil is to be arranged to come automatically into use in the event of a failure of the supply from the pump.

The emergency supply may be obtained from a gravity tank containing sufficient oil to maintain adequate lubrication for not less than 6 minutes, and in the case of propulsion turbo-generators until the unloaded turbine comes to rest from its maximum rated running speed. Alternatively, the supply may be provided by the stand-by pump or by an emergency pump. These pumps are to be so arranged that their availability is not affected by a failure in the power supply.

Filters

906 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing the supply of filtered oil to the engine.

907 Where filters are fitted on the discharge side of the lubricating oil pump, a relief valve in close circuit is to be fitted between the pump and the filter if the pump is capable of developing a pressure exceeding the design pressure of the system.

908 In the case of propulsion turbines and their gears, arrangements are to be made for the lubricating oil to pass through magnetic strainers and fine filters.

Note: It is recommended that the openings in the filter elements be not coarser than 50 microns (0.002 in), especially for the supply to turbine thrust bearings.

Pipes and Fittings

909 Extreme care is to be taken to ensure that lubricating oil pipes and fittings, before installation, are free from scale, sand, metal particles and other foreign matter.

Lubrication of Bearings

910 The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gear cases, electric generators, motors and other running machinery are to be so designed that lubrication will remain efficient with the ship inclined from the normal at any angle up to 15 degrees transversely and when pitching 10 degrees longitudinally and when rolling up to 22,5 degrees from the vertical.

911 For details of the requirements relating to the lubrication of bearings of electric generators and motors, see M 107.

Valves and Cocks

912 Outlet valves and cocks on lubricating oil service tanks, other than double bottom tanks, situated in machinery spaces are to be capable of being closed locally and from positions outside the compartment which will always be accessible in the event of fire occurring in these spaces. Remote controls need only be fitted to outlet valves and cocks which are open in normal service and are not required for other outlets

such as those on storage tanks. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

In the case of very small tanks consideration will be given to the omission of remote controls.

Cross-References

913 For air and sounding pipes and gauge glasses, see E 404, E 413 and E 415.

Section 10

PUMPING ARRANGEMENTS FOR SHIPS NOT FITTED WITH PROPELLING MACHINERY

Hand Pumps

1001 Where auxiliary power is not provided, hand pumps are to be fitted in number and position as may be required for the efficient drainage of the ship.

The pumps are to be capable of being worked from the upper deck or from positions above the load waterline which are at all times readily accessible.

The suction lift is not to exceed 7,3 m (24 ft), and is to be well within the capacity of the pump.

1002 The sizes of the hand pumps are not to be less than given in Table E 10.1.

TABLE E 10.1

	Hand Pumps			
Tonnage under Upper Deck	Diameter of barrel of bucket pump mm (in)	Bore of suction pipe of bucket pumps and semi- rotary pumps mm (in)		
Not exceeding 500 tons	100	50 (2)		
Above 500 tons but not exceeding 1000 tons	115 (4·5)	57 (2·25)		
Above 1000 tons but not exceeding 2000 tons	125 (5)	65 (2·5)		
Above 2000 tons	140 (5·5)	70 (2·75)		

Where the ship is closely subdivided into small watertight compartments 50 mm (2 in) bore suctions will be accepted.

Power Pumps

1003 In ships in which auxiliary power is available on board, power pump suctions are to be provided for dealing with the drainage of tanks and of the bilges of the principal compartments.

The pumping arrangements are to be as required for self-propelled ships in so far as these requirements are applicable, duly modified to suit the size and service of the ship.

Details of the pumping arrangements are to be submitted for special consideration.

Section 11

PETROLEUM AND OTHER LIQUID CARGOES HAVING A FLASH POINT BELOW 60°C (140°F) (CLOSED CUP TEST)

General

1101 The following requirements are based on the assumption that the ships are of normal tanker type having the main propelling machinery aft.

Departures from normal type will require special consideration.

Cargo Oil System

- 1102 A complete system of piping and pumps is to be fitted for dealing with the cargo oil.
- 1103 Cargo pump rooms are to be enclosed by oiltight bulkheads and are to have no direct communication with machinery spaces.
- 1104 Pumps for the purpose of filling or emptying the cargo oil tanks are to be used exclusively for this purpose, except as provided in 1107. They are not to have any connections to compartments outside the range of cargo oil tanks.

Means are to be provided for stopping the cargo oil pumps from a position outside the pump rooms, as well as at the pumps.

- 1105 The pumps are to be provided with effective escape valves which are to be in close circuit, i.e., discharging to the suction side of the pumps.
- 1106 Expansion joints or bends are to be provided where necessary in the cargo pipe lines.

Terminal pipes, valves and other fittings in the cargo loading and discharging lines to which shore installation hoses are directly connected are to be of steel or other approved ductile material. They are to be of robust construction and strongly supported.

of the cargo pump rooms by pump or bilge ejector suctions. The cargo pumps or cargo stripping pumps may be used for this purpose, provided the bilge suctions are fitted with screw-down non-return valves and, in addition, an isolating valve or cock be fitted on the pump connection to the bilge chest. The pump room bilges of small tankers may be drained by means of a hand pump having a 50 mm (2 in) bore suction.

Pump room suctions are not to enter machinery spaces.

- 1108 Pump rooms are to be provided with ready means of access and adequate ventilation.
- 1109 Ullage plugs or sighting ports are to be provided at each tank to enable the amount of ullage to be ascertained.

Ullage plugs or sighting ports should not be fitted in any enclosed space.

- 1110 Provision is to be made for the gas freeing of the cargo oil tanks when the cargo has been discharged and for the ventilation and gas freeing of all compartments adjacent to cargo oil tanks.
- 1111 Vapour pipes are to be fitted to cargo oil tanks and connected through shut-off valves or cocks or pressure-vacuum valves to a vapour line led up the mast or other post to a safe height above the weather deck. The outlets from these vapour mains are to be provided with readily renewable wire gauze or safety heads of approved types. If alternative means of dealing with the vapour are desired, details are to be submitted.

Bilge, Ballast, Oil Fuel and other Piping not within the Cargo Oil System

- 1112 The pumping arrangements in the machinery space and at the forward end of the ship are to comply with the requirements for general cargo ships in so far as they are applicable and with the special requirements detailed in 1113 to 1117.
- 1113 A separate power pump is to be fitted in a suitable compartment forward of the cargo tanks to deal with bilge drainage, water ballast and oil fuel pumping at the fore end of the ship.

In small tankers, a forward power pump may be dispensed with, provided suitable alternative arrangements are made, details of which are to be submitted.

- 1114 Where deep cofferdams can be filled with water ballast, a ballast pump in the main engine room may be used for emptying the after cofferdam, provided the suction be led direct to the pump and not to an engine room pipe system. The ballast pump in the forward pump room may be used for emptying the forward cofferdam.
- 1115 Cofferdams are not to have any direct connections to the cargo oil tanks or cargo oil lines.

Where intended to be dry compartments, after cofferdams adjacent to the pump room may be drained by a cargo pump, provided isolating arrangements are fitted in the bilge system as required by 1107; forward cofferdams may be drained by the bilge and ballast pump in the forward pump room. Alternatively, cofferdams may be drained by hand pumps or bilge ejectors.

Cofferdams are to be provided with sounding pipes and with air pipes led to the open. These air pipes are to be fitted with wire gauze diaphragms at their outlets.

1116 Bilge, ballast, oil fuel and other piping connected to the pumps at the ends of the ship are not to pass through the cargo oil tanks or have any connection with these tanks.

Cargo oil pipes are not to pass through ballast or oil fuel tanks or through compartments which are external to the cargo oil system.

1117 The oil fuel bunkering system is to be entirely separate from the cargo oil system.

Steam and Exhaust Piping

1118 Where heating coils are provided in the cargo oil tanks they are to be made and fitted under the usual conditions of survey and testing. (See E 334 to E 336, E 524 and E 601 to E 607.)

An observation tank is to be provided for the heating coil drains and is to be situated in a well ventilated and well lighted part of the machinery space remote from the boilers.

Spectacle flanges are to be provided in the main steam and exhaust pipes to the cargo oil heating system, at a suitable position forward of the machinery space bulkhead, so that the lines can be blanked off in circumstances where cargo oil does not require to be heated or where heating coils are not fitted in the tanks.

1119 Steaming out and fire extinguishing connections for cargo oil tanks or cargo oil pipe lines are to be fitted with valves of non-return type and the main supply to these connections is to be fitted with a master valve placed in a readily accessible position clear of the tanks.

1120 In the cargo pump rooms, drain pipes from steam or exhaust pipes or from the steam cylinders of the pumps are to terminate well above the level of the bilges.

Motive Power of Cargo Oil Pumps

1121 Where the cargo oil pumps are not driven by steam, plans of the arrangements for driving the pumps are to be submitted.

1122 Where cargo pumps are driven by shafting which passes through a pump room bulkhead or deck, gastight glands with efficient means of lubrication are to be fitted to the shaft at the pump room plating.

Auxiliary Machinery outside Main Engine Room

1123 Oil engines are not to be situated within pump rooms, cofferdams or other spaces liable to contain petroleum or other explosive vapours.

(For requirements for electrical equipment within such spaces, see M 16.)

Section 12

LIQUEFIED GASES

General

1201 The following requirements are intended primarily for liquefied Methane, Propane, Butane and other petroleum gases but may be applied to other liquefied gases with comparable properties and carrying hazards subject to special consideration in each case.

PART 1

LIQUEFIED PETROLEUM GASES CARRIED IN INDE-PENDENT SPHERICAL OR CYLINDRICAL TYPE TANKS AT PRESSURES ABOVE 0,7 kg/cm² (10 lb/in²) AND AT AMBIENT OR LOWER TEMPERATURES Plans

1202 Plans showing filling, discharging, venting and inerting pipe arrangements, together with particulars of the intended cargo, maximum vapour pressure and minimum liquid temperature are to be submitted.

Hold Drainage

1203 Provision is to be made for the drainage of holds in which the cargo tanks are situated. Normal drainage is to be effected by hand pumps, bilge ejectors or other approved

means. Hand pumps are to be made of gunmetal or other non-ferrous material and are to be fitted on deck having discharges directly overboard. Bilge ejectors are to be fitted in the holds and may be operated by steam or water.

1204 In addition to the above requirements, bilge suctions as required by E 2 are to be provided for use in an emergency. These suctions are to be led direct to the bilge pump suction chest and are to be blanked off in normal service by spectacle blank flanges in readily accessible positions in the machinery space. Screw-lift valves are to be fitted between the spectacle flanges and the bulkhead so that the pipes can be isolated if it is necessary to change over the spectacle flanges. Notice plates are to be fitted in the vicinity of the valves stating that the bilge suctions are not to be used except in case of grave emergency.

A brass rod is to be provided for sounding the holds.

Connections to Cargo Tanks

1205 Cargo tanks are to be provided with the necessary connections for liquid and gas lines, relief valves, liquid level gauging devices, pressure gauges and thermometers.

1206 All connections are to be situated above the weather deck and protected from damage.

Shut-off Valves

1207 Connections for filling and emptying the cargo tanks of liquid or gas are to be fitted with double shut-off valves: one is to be a manually operated shut-off valve and the other one of the following:—

- (a) a remote controlled valve which is capable of being closed from the loading station and at least two other widely separated positions on the upper deck, or
- (b) an excess flow valve which will close automatically and prevent the tank emptying in the event of a pipe breaking.

In the case of single purpose connections which are required only for the inlet of liquid or gas a non-return valve would be accepted in place of (a) or (b) above.

Shut-off valves are to be fitted with legible nameplates in prominent positions.

Pressure Relief Valves

1208 Each cargo tank is to be protected by one or more pressure relief valves of approved design and capacity discharging into a vapour relief main led up the mast or other post to a safe height above the weather deck and well removed from possible sources of ignition.

The relief valves should be of sufficient capacity to discharge the vapours formed by exposure of the cargo tank walls to fire. Calculations on which the area of the valves are based are to be submitted.

In every case the combined discharge capacity of the pressure relief valves is to be sufficient to prevent a rise of pressure in the tank to more than 10 per cent above the design vapour pressure.

The discharge capacity of a pressure relief valve is to be established by type tests carried out in the presence of the Surveyors or by an independent authority recognized by the Society.

Pressure relief valve connections are to be attached to the tanks near the highest part of the vapour space.

Shut-off valves are not to be fitted between the tanks and the pressure relief valves unless there are two or more relief valves per tank and the shut-off arrangements are so devised that pressure relief valves having the required discharge capacity are always in communication with the tank.

Shut-off valves are not to be fitted between the pressure relief valves and the vapour relief main outlet.

Each pressure relief valve is to be tested in the presence of the Surveyors to demonstrate that it commences to discharge at a pressure not more than 3 per cent above the maximum vapour pressure for which the tanks have been approved.

Vacuum Relief Valves

1209 Consideration should be given to the ability of the cargo tanks to withstand any vacuum which may arise in service or when the tanks are being gas freed. Where necessary, vacuum relief valves are to be fitted and vacuum relief obtained from a supply of cargo gas or an inert gas system.

Vapour Relief Systems

1210 The vapour relief main is to have a cross-sectional area equal to the combined area of the branch vapour relief pipes, but if there are three or more cargo tanks the following percentage reductions in the area of the vapour relief main will be allowed:—

3 cargo tanks 10% reduction

4 ,, ,, 20% ,,

5 ,, ,, 30% ,,

6 ,, ,, 40%, ,,

or more

The vapour relief system outlet is to be arranged to discharge the gases in a direction above the horizontal and the outlet is to be fitted with a flameproof wire gauze diaphragm and protected from the weather. Suitable drainage arrangements for condensate water are to be provided for the vapour relief lines.

Level Gauges

1211 Liquid level gauging devices are to be of approved type and are to indicate the maximum level to which the tank may be filled having regard to the nature of the cargo and its temperature.

Pressure Gauges

1212 Pressure gauges are to be marked with the working pressure of the tank. Pressure gauge connections are to be fitted with a manually operated shut-off valve.

Cargo Handling System

1213 A complete cargo handling system is to be provided for dealing with the cargo. The system is to be used exclusively for this purpose and is not to have connections to compartments outside the range of the cargo tanks.

Certain items in the system may be inaccessible with cargo on board and where such items are of new design or have not been previously subjected to working conditions similar to those contemplated in service (e.g., pumps and associated driving equipment), prototype tests are to be carried out and the results submitted for approval.

All piping in the cargo handling system is to be situated above the weather deck.

1214 All materials used in the piping systems must be suitable for the proposed service. Where the operating metal temperature is below 0°C (32°F), specifications of the materials for pipes and fittings giving chemical composition and mechanical properties at the service temperature are to be submitted for approval.

1215 All piping, valves and fittings are to be suitable for the maximum pressure to which the system may be subjected, but not, in any case, less than a pressure of 10,5 kg/cm² (150 lb/in²).

Piping subject to pressure is to be of seamless or other approved type and is to comply with the requirements of E 5.

Valves and fittings are to be of steel or other approved ductile material.

- 1216 Joints may be of butt-welded or flanged type. Couplings of approved type may be used for joints 38 mm (1.5 in) diameter or smaller. Low grade screwed joints are not acceptable.
- 1217 Provision is to be made in the pipe lines for the effects of expansion and contraction. If expansion pieces are used they are to be of the bellows type. All piping is to be suitably supported and secured.
- 1218 Low temperature pipes are to be protected against external corrosion, adequately insulated and provided with temperature isolation from the hull. Drip trays are to be fitted where cargo leakage or spillage is likely to occur.
- 1219 Sections of piping which may contain liquid gas and which can be isolated are to be provided with relief valves discharging to the vapour relief main or other safe position.
- 1220 Connections are to be provided so that the cargo tanks and the cargo handling system can be purged with an inert gas. Provision is also to be made for the gas-freeing of the cargo tanks.
- 1221 Terminal pipes, valves and fittings in the cargo handling system, to which shore installation hoses are directly connected, are to be of robust construction and strongly supported.

Suitable arrangements are to be provided for relieving the liquid and gas lines of internal pressure before the shore installation hoses are disconnected.

Earthing of Tanks and Pipes

1222 Where tanks and pipes are separated from the hull structure by insulating materials they are to be effectively earthed to the hull by at least two earthing connections as a precaution against the effects of static charges.

Cargo Pumps and Gas Compressors

- 1223 Pumps and compressors may be installed on the open deck provided they are suitably located and protected from mechanical damage. Alternatively, the pumps and compressors may be fitted in a well-ventilated compartment outside the machinery space. This compartment is to be treated as a dangerous space to which the requirements of M 16 for electrical equipment are applicable.
- 1224 Where pumps and compressors are driven by shafting which passes through a bulkhead, gastight glands with efficient means of lubrication are to be fitted to the shafts in way of the bulkhead.

- 1225 The pumps are to be fitted with relief valves if they are capable of developing a discharge pressure greater than the design pressure of the piping system. The relief valves are to discharge to the suction side of the pumps.
- 1226 Compressors are to be fitted with relief valves discharging to the vapour relief main, or other safe position. The relief valves are to be so proportioned and adjusted that the accumulation with the outlet valves closed will not exceed 10 per cent of the maximum working pressure.
- 1227 The pumps and compressors are to be capable of being stopped from the loading station and from a position outside the range of the cargo tanks.

Refrigeration Equipment and Piping

1228 Where the cargo is refrigerated or the boil-off is re-liquefied, the arrangements will be specially considered. In ships classed for unrestricted service the capacity of the refrigerating machines is to be based on a sea temperature of 30°C (86°F) and on an ambient air temperature of 45°C (113°F). Two or more refrigerating units are to be provided of capacity sufficient to maintain the liquid cargo at the carrying temperature with any one unit out of use.

PART 2

LIQUEFIED METHANE AND PETROLEUM GASES CARRIED IN INDEPENDENT RECTANGULAR TYPE TANKS AT PRESSURES OF 0,7 kg/cm² (10 lb/in²) OR LESS AND AT TEMPERATURES BELOW AMBIENT

The following paragraphs of Part 1 are applicable:—

Plans	***				1202
Connecti	ons t	o Cargo	Tank	s	1205 and 1206
Pressure	Relie	f Valv	es		1208
Vacuum	Relie	f Valv	es	***	1209
Vapour :	Relief	System	n		1210
Cargo Pi	ping	System		***	1214 to 1221
					inclusive
Earthing	of T	anks ar	nd Pipe	s	1222
Refriger					
Piping			***	***	1228

Shut-off Valves

1229 Each cargo tank is to be provided with separate connections for cooling down, filling and discharge purposes. These connections are to have shut-off valves or cocks manually controlled and fitted with legible nameplates in a prominent position.

Filling connections are to be provided with internal pipes led to the bottom of the tanks.

Level Gauges

1230 An approved liquid level gauging device of the closed type is to be provided for each tank. This gauge should be arranged to give audible and visible warning of the high and low liquid levels in the tank.

An independent high level alarm device is also to be provided for each tank which, besides giving audible and visible warning of over-filling, is capable of closing the terminal valve at the cargo loading station.

Liquid level gauging and alarm devices are to be adequately protected against damage.

Pressure Gauges

1231 Means are to be provided for indicating the pressure in each cargo tank and containment space.

Thermometers

1232 Thermometers are to be of the remote reading type and are to be marked with the minimum permitted carrying temperature for the tank.

Instrument and Control Rooms

1233 Gas detection, pressure recording, safety and alarm devices, etc., are to be installed in a well ventilated room in an approved position.

Where gas detecting devices are fitted in a room containing electrical equipment which is not intrinsically safe, the arrangements are to be such that there is no possibility of gas leakage reaching the electrical equipment. Details are to be submitted.

Cargo Handling System

1234 A complete cargo handling system is to be provided for dealing with the cargo. The system is to be used exclusively for this purpose and is not to have connections to compartments outside the range of the cargo tanks.

Certain items in the system may be inaccessible with cargo on board and where such items are of new design or have not been previously subjected to working conditions similar to those contemplated in service (e.g., pumps and associated driving equipment), prototype tests are to be carried out and the results submitted for approval.

15th July, 1971

Terminal valves at the loading station are to be capable of being closed locally and from at least two other widelyseparated positions on the upper deck.

All piping in the cargo handling system is to be situated above the weather deck.

Emergency Discharge of Cargo

1235 Where cargo tanks are surrounded by void spaces, provision is to be made for draining such spaces in the event of tank leakage or rupture.

Arrangements are to be made so that the liquid cargo can be discharged overboard in an emergency. The discharge nozzle should preferably be at the stern of the ship and so designed that the liquid discharge will reach the water as far from the ship as possible.

Cargo Pumps

1236 All cargo pumps are to be capable of being stopped from the loading station and from a position outside the range of the cargo tanks. The pumps are to be fitted with relief valves if they are capable of developing a discharge pressure greater than the design pressure of the piping system. The relief valves are to discharge to the suction side of the pump.

Stand-by means for pumping out each cargo tank are to be provided.

1237 In the case of deep well pumps driven from positions above the cargo tanks, gastight glands with efficient means of lubrication are to be provided where the driving shafts enter the tanks.

1238 If the cargo pumps are driven by submerged electric motors, the arrangements will be subject to special consideration and must ensure that under all conditions air will not be admitted to the cargo tanks.

Cross-references

1239 Cargo tanks are to be constructed as required by J 7 or D 71 whichever is applicable.

Ventilation arrangements are to comply with ... D 72

Electrical arrangements are to comply with ... M 16

The use of Methane as fuel for propulsion
purposes ... see Chapter R (A)

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Chapter F

FIRE PROTECTION, DETECTION AND EXTINCTION

PART 1

FIRE DETECTION AND EXTINCTION IN PASSENGER, CARGO AND OTHER SHIPS

Section 1

GENERAL

101 The requirements of Part 1 of this Chapter apply to passenger and cargo ships to be classed for unrestricted service.

102 While the requirements satisfy the regulations of the International Convention for the Safety of Life at Sea, 1960, attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered. Compliance with these statutory requirements may be accepted as meeting the requirements of this Chapter.

103 Consideration will be given to special cases where the arrangements are equivalent to those required by these Rules. Consideration will also be given to fire extinguishing equipment and arrangements for small ships and ships to be classed for restricted or special service.

104 Fire fighting appliances—hoses, extinguishers, gas cylinders, emergency pumps, breathing apparatus, fireman's axe, etc.—which have been approved by a National Authority as complying with the regulations of the International Convention for Safety of Life at Sea, 1960, may be accepted as meeting the requirements of this Chapter.

105 Where it is proposed to apply centralised, bridge, or automatic controls to propulsion machinery and essential auxiliaries and it is intended that the engine and/or boiler rooms will not be continuously manned at sea, an approved fire detection system, in accordance with F 326 to F 328, is to be provided in these spaces (see Chapter L).

Note. Having regard to the greater fire risk when a ship is in port, and the possibly reduced level of manning, it is recommended that an approved fire detection system, in accordance with F 326 to F 328, should be provided in engine and/or boiler rooms not fitted with the type of controls indicated in 105.

Section 2

PUMPS, WATER SERVICE PIPES, HYDRANTS AND HOSES

Total Capacity of Fire Pumps

201 In a passenger ship, the required fire pumps of F 4 are to be capable of delivering for fire fighting purposes a quantity of water not less than two-thirds of the total quantity required to be dealt with by the bilge pumps when employed for bilge pumping. (See E 239 for number and capacity of bilge pumps.)

The fire pumps are to be capable of developing the pressures in the fire main as required by 206.

202 In a cargo ship, the required fire pumps of F 5, other than the emergency pump (if any), are to be capable of delivering for fire fighting purposes a quantity of water not less than two-thirds of the total quantity required to be dealt with by the bilge pumps when employed for bilge pumping, except that in cargo ships the total required capacity of the fire pumps need not exceed 180 m³ (180 tons) per hour. (See E 205 for number and capacity of bilge pumps).

The fire pumps are to be capable of developing the pressures in the fire main as required by 206.

Fire Pumps

203 Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil and that if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable change-over arrangements are fitted.

In ships classed for navigation in ice, the fire pump sea inlet valves are to be provided with clearing arrangements as required by H 509 and H511, or H 537, as applicable.

Chapter F

204 Any pump designated as a fire pump (other than any emergency pump required by F 505) is to have a capacity not less than 80 per cent of the total required capacity divided by the number of required fire pumps and in any event is to be capable of delivering at least the two required jets of water. Any deficiency in capacity of one of the fire pumps is to be made good by excess capacity of the other fire pumps. These fire pumps are to be capable of supplying the fire main system under the required conditions.

Where more pumps than required are installed their capacities will be specially considered.

205 Relief valves are to be provided in conjunction with all fire pumps if the pumps are capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

Pressure in the Fire Main

206 The fire pumps, associated piping and fire main are to be so designed that the following minimum pressures will be maintained at all hydrants under conditions where the two fire pumps required by 201 or 202 are simultaneously delivering water to the fire main of size required by 207 through adjacent nozzles of sizes required by 215.

PASSENGER SHIPS

4000 tons gross and over ... 3,2 kg/cm² (45 lb/in²).

1000 tons gross and over but 2,8 kg/cm² (40 lb/in²).

under 4000 tons gross

Under 1000 tons gross ... A pressure sufficient to produce a 12,2 m (40 ft) jet throw required by 215 to the satisfaction of the Surveyors.

CARGO SHIPS

6000 tons gross and over ... 2,8 kg/cm2 (40 lb/in2).

1000 tons gross and over but $2.6 \text{ kg/cm}^2 (37 \text{ lb/in}^2)$.

under 6000 tons gross

Under 1000 tons gross ... A pressure sufficient to produce a 12,2 m (40 ft) jet throw required by 215 to the satisfaction of the

Surveyors.

Fire Main

207 The diameter of the fire main is to be based on the required capacity of two fire pumps and the diameters of the water service pipes are to be sufficient to ensure an adequate supply of water for the simultaneous operation of at least two fire hoses. In general, the diameter of the fire main should not be less than that required by the following formula but is in no case to be less than 50 mm (2 in):—

$$d = \frac{L}{1,2} + 25 \text{ mm}$$
 $\left(d = \frac{L}{100} + 1 \text{ in}\right)$

when d = internal diameter of the fire main, in mm (in), L = Rule length of the ship, in metres (feet).

The diameter of the fire main need not exceed 127 mm (5 in) in cargo ships and 178 mm (7 in) in passenger ships.

208 The fire main is to be situated outside the machinery spaces and the discharge line or lines from the fire pumps are to be fitted with isolating valves at the connections to the fire main. Where the machinery space is situated amidships isolating valves are also to be provided in the fire main so that the hydrants at both ends of the ship may be used simultaneously or separately.

209 The wash deck line may be used as a fire main provided the requirements of this Section are satisfied.

210 All water pipes for fire extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged by cargo.

Number and Position of Hydrants

211 The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant, one of which is to be from a single length of hose, may reach any part of the ship. In ships of 1000 tons gross and over two hydrants are to be provided in the machinery spaces: in smaller ships one hydrant will be accepted.

Pipes and Hydrants

212 Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire hoses may be easily coupled to them. In ships where deck cargo may be carried, the positions of the hydrants are to be such that they are always readily accessible and the pipes are to be arranged as far as practicable to avoid risk of damage by such cargo. Unless there is provided one hose and nozzle for each hydrant in the ship there shall be complete interchangeability of hose couplings and nozzles.

213 Valves or cocks are to be fitted in such positions on the pipes that any of the fire hoses may be removed while the fire pumps are at work.

Fire Hoses

214 Fire hoses are to be of leather, seamless hemp, close weave flax canvas, or other approved material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length in general is not to exceed 18,3 m (60 ft). Each hose is to be provided with a nozzle and the necessary couplings. Fire hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

Nozzles

215 The nozzles used for extinguishing fires other than oil fires are to have a bore of not less than 12 mm (0·5 in). For accommodation and service spaces, a nozzle size of 12 mm (0·5 in) will normally be adequate but for machinery spaces and exterior locations 12, 16 or 20 mm (0·5, 0·625 or 0·75 in) nozzles may be adopted so as to make full use of the

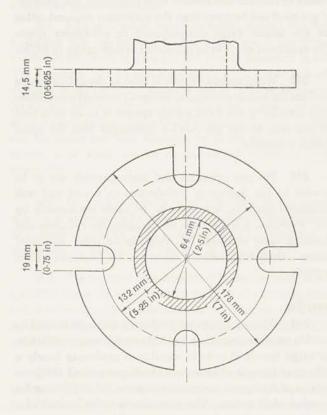


Fig. F 2.1

maximum discharge capacity of the fire pumps. The jet throw at any nozzle is to be about 12,2 m (40 ft). Dual purpose nozzles for jet or fog may be adopted.

International Shore Connection

216 The international shore connection required by F 408 and F 509 is to be suitable for a working pressure of 10,5 kg/cm² (150 lb/in²). It is to have on one side a flat faced flange with dimensions as shown in Fig. F 2.1, and on the other side a permanently attached coupling that will fit the ship's hydrants and hose. The connection is to be kept aboard the ship together with a gasket suitable for 10,5 kg/cm² (150 lb/in²) service, together with four 16 mm (0.625 in) bolts, 50 mm (2 in) in length, and eight washers.

Section 3

FIRE EXTINGUISHERS AND EXTINGUISHING SYSTEMS

Fire Extinguishers (Portable and Non-Portable)

301 All fire extinguishers are to be approved types. If considered necessary, the Committee may require the makers to produce evidence from a recognised independent testing authority regarding the suitability of their appliances.

302 The extinguishers required for use in the machinery spaces of ships burning oil as fuel are to be of a type discharging froth, carbon dioxide gas, dry powder, or other approved medium suitable for extinguishing oil fires.

Fire extinguishers containing an extinguishing medium which either itself or when in use gives off gases harmful to persons are not to be used. For radio rooms and switch-boards extinguishers containing not more than 1,136 litres (1 quart) of carbon tetrachloride or similar media may be permitted subject to such extinguishers being additional to any required by F 4 and F 5.

303 The capacity of required portable fluid extinguishers is not to be more than 13,5 litres (3 gallons) and not less than 9 litres (2 gallons). Other extinguishers are not to be in excess of the equivalent portability of the 13,5 litre (3 gallon) fluid extinguisher and are not to be less than the fire extinguishing equivalent of a 9 litre (2 gallon) fluid extinguisher.

304 A spare charge is to be provided for each required portable fire extinguisher which can be readily re-charged on board. If this cannot be done, duplicate extinguishers are to be provided.

305 One of the portable fire extinguishers intended for use in any space is to be stowed near the entrance to that space.

Acceptable Equivalents

306	FROTH	CARBON DIOXIDE
	136 litres (30 gallons)	45 kg (100 lb)
	45 litres (10 gallons)	16 kg (35 lb)
	Portable	4,5 kg (10 lb)

Fire-Smothering Gas or Steam for Machinery and Cargo Spaces

307 Where provision is made for the injection of gas into machinery spaces or gas or steam into cargo spaces for fire extinguishing purposes, the necessary pipes for conveying the gas or steam are to be provided with control valves or cocks which are to be so placed that they will be easily accessible and not readily cut off from use by an outbreak of fire. These control valves or cocks are to be so marked as to indicate clearly the compartments to which the pipes are led. Suitable provision is to be made to prevent inadvertent admission of the gas or steam to any compartment. Where cargo spaces, fitted with smothering equipment for fire protection, are used as passenger spaces the smothering connections are to be blanked during service as a passenger space. Blank flanges fitted in gas or steam distribution pipes are to be of the "spectacle" type. The nuts for the securing bolts are to be of non-corrodible metal.

308 The piping is to be of adequate size and so arranged to provide effective distribution of fire-smothering gas or steam. In holds exceeding 18,3 m (60 ft) in length, there are to be at least two pipes, one of which is to be fitted in the forward part and one in the after part; the steam pipes are to be led well down in the space as remote as possible from the shell. Separate pipes are to be provided for lower hold and 'tween decks. All pipes are to be arranged to be self-draining and are not to be led through refrigerated spaces unless the pipes are specially insulated. Steel distribution pipes are to be galvanised internally and externally and are not to be smaller than 20 mm (0.75 in) bore for carbon dioxide and 25 mm (1 in) bore for steam and inert gas.

In tankers, the piping system is to be so arranged that the gas or steam will be distributed over the surface of the cargo. See also F 513.

Carbon Dioxide Gas

309 When carbon dioxide is used as the extinguishing medium in cargo spaces, the quantity of gas available is to be sufficient to give a minimum volume of free gas equal to 30 per cent of the gross volume of the largest cargo compartment in the ship which is capable of being sealed.

- 310 When carbon dioxide is used as an extinguishing medium for spaces containing boilers or internal combustion type machinery, the quantity of gas carried is to be sufficient to give a minimum volume of free gas equal to the larger of the following, either:—
 - (1) 40 per cent of the gross volume of the largest space, the volume to include the casing up to the level at which the horizontal area of the casing is 40 per cent or less of that of the space concerned; or
 - (2) 35 per cent of the entire volume of the largest space including the casing;

provided that the above mentioned percentages may be reduced to 35 per cent and 30 per cent respectively for cargo ships of less than 2000 tons gross; provided also that if two or more spaces containing boilers or internal combustion type machinery are not entirely separate they are to be considered as forming one compartment.

When evaluating the quantity of carbon dioxide gas required for the machinery spaces of motor ships, the free air content of the main starting air receivers is to be added to the above gross space volumes. See also J 640.

- 311 When carbon dioxide is used as an extinguishing medium both for cargo spaces and for spaces containing boilers or internal combustion type machinery the quantity of gas need not be more than the maximum required either for the largest cargo compartment or machinery space. The volume of gas is to be calculated at 0,56 m³/kg (9 ft³/lb).
- 312 When carbon dioxide is used as the extinguishing medium for spaces containing boilers or internal combustion type machinery the fixed piping system is to be such that 85 per cent of the gas can be discharged into the space within 2 minutes.
- 313 The gas cylinders and main controls are to be located to the Surveyors' satisfaction in a cool and well ventilated position, not likely to be made inaccessible by fire. Provision is to be made for changing the cylinders and checking their contents by weighing or other approved means. Operating instructions are to be displayed at the controls.

Inert Gas

314 Where a generator producing inert gas is used to provide smothering gas in a fixed fire-smothering installation for cargo spaces, it is to be capable of producing hourly a volume of free gas at least equal to 25 per cent of the gross volume of the largest compartment protected in this way for a period of 72 hours. The generator is to be located in a position not likely to be made inaccessible by fire.

Steam

315 When steam is used as the extinguishing medium in cargo spaces the boiler or boilers available for supplying steam are to have an evaporation of at least I kg of steam per hour for each 0,75 m³ (1 lb for each 12 ft³) of the gross volume of the largest cargo compartment in the ship. It is required that steam will be available immediately and will not be dependent on the lighting of boilers and that it can be supplied continuously until the end of the voyage in the required quantity in addition to any steam necessary for the normal requirements of the ship including propulsion and that provision is made for extra feed water necessary to meet this requirement.

Steam is not to be used in spaces containing explosives.

Steam used for fire extinguishing purposes is not to be obtained from a supply of super-heated steam.

Audible Alarms

316 Means are to be provided whereby audible warning is given automatically before fire-smothering gas can be released into the machinery space and any other working space.

Automatic Sprinkler Systems

- 317 Any automatic water sprinkler system for fire protection is to be designed for immediate use at any time, so that no action on the part of the crew is necessary to set it in operation. Where such a system is fitted, it is to be kept charged at the necessary pressure and is to have provision for a continuous supply of water. The distribution pipes are to be of steel or other approved material of adequate strength and the mains and their branches up to the section control points, if of steel, are to be galvanized internally and externally.
- 318 The system is to be sub-divided into an approved number of sections, and automatic alarms are to be provided to indicate at one or more suitable points or stations the occurrence or indication of fire, and its location.
- 319 The pump or pumps to provide the discharge from sprinkler heads are to be so connected as to be brought into action automatically by a pressure drop in the system. There is to be a connection from the ship's fire main provided with a lockable screw-down valve and a non-return valve.
- 320 Each pump is to be capable of maintaining a sufficient supply of water at the appropriate pressure, at the sprinkler heads, while such number of sprinkler heads as may be approved are in operation.

- 321 In passenger ships there are not to be less than two sources of power supply for the sea water pumps, air compressors and automatic alarms. Where the sources of power are electrical, these are to be a main generator and an emergency source of power. One supply is to be taken from the main switchboard by separate feeders reserved solely for that purpose. Such feeders are to be run to a change-over switch situated near to the sprinkler unit and the switch shall normally be kept closed to the feeder from the emergency switchboard. The change-over switch is to be clearly labelled, and no other switch except those at the switchboards is to be permitted in these feeders.
- 322 Sprinkler heads are required to operate at temperatures between 68°C and 93°C (155°F and 200°F) except in drying rooms and other hot spaces. Suitable means for the periodic testing of all automatic arrangements are to be provided.
- 323 Where a sprinkler system of fire protection is employed in a ship the superstructure of which is constructed in aluminium alloy, the whole unit including the sprinkler pump, tank and air compressor is to be situated in an approved position reasonably remote from the boiler and machinery spaces. If the feeders from the emergency generator to the sprinkler unit pass through any space constituting a fire risk the cables are to be of a fireproof type.

Fixed Froth Fire Extinguishing System

- 324 Any required fixed froth fire extinguishing system is to be able to discharge a quantity of froth sufficient to cover to a depth of 150 mm (6 in) the largest area over which oil fuel is liable to spread.
- 325 Such a system is to be controlled from an easily accessible position or positions, outside the space to be protected, which will not be readily cut off by an outbreak of fire. The distribution pipes are to be of steel galvanized internally and externally.

Fire Detection Systems

- 326 All required fire detection systems are to be capable of automatically indicating the presence or indication of fire and its location. Indicators are to be centralized either on the bridge or in other control stations which are provided with a direct communication with the bridge. The indicators may be distributed among several stations subject to approval by the Surveyors.
- 327 Electrical equipment used in the operation of required fire detection systems is to have two separate sources of power, one of which should be an emergency source.

328 The alarm system is to operate both audible and visible signals at the main stations referred to in 326. Detection systems for cargo spaces need not have audible alarms. Where it is intended that the engine and/or boiler rooms will not be continuously manned at sea, the alarm system is to operate both audible and visible signals at the station from which the machinery is controlled, which should be in direct communication with the bridge. When control is effected from the bridge only, the alarms must operate also in the Engineer Officers' accommodation.

Fixed Pressure Water-Spraying Systems for Engine Rooms and Boiler Rooms

329 Fixed pressure water-spraying systems for boiler rooms with oil fired boilers and engine rooms with internal combustion type machinery are to be provided with spraying nozzles of an approved type.

330 The number and arrangement of the nozzles are to be to the satisfaction of the Surveyors and be such as to ensure an effective distribution of water in the spaces to be protected. Nozzles are to be fitted above bilges, tank tops and other areas over which oil fuel is liable to spread and also above oil fuel settling and service tanks, heaters, pumping units, purifiers and other main fire hazards in the boiler and engine rooms.

331 The system may be divided into sections, the distribution manifolds of which are to be operated from easily accessible positions outside the spaces to be protected and which will not be readily cut off by an outbreak of fire.

332 The system is to be kept charged at the necessary pressure and the pump supplying the water for the system is to be put automatically into action by a pressure drop in the system.

333 The pump is to be capable of simultaneously supplying at the necessary pressure all sections of the system in any one compartment to be protected. The pump and its controls are to be installed outside the space or spaces to be protected. It is not to be possible for a fire in the space or spaces protected by the water-spraying system to put the system out of action.

334 Special precautions are to be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of piping, nozzles, valves and pump.

Fireman's Outfit

335 A fireman's outfit is to consist of a breathing apparatus, a lifeline, a safety lamp and an axe, as described in this paragraph.

The breathing apparatus is to be of an approved type and may be either (1) or (2):—

- (1) A smoke helmet or smoke mask which is to be provided with a suitable air pump and a length of air hose sufficient to reach from the open deck, well clear of hatch or doorway, to any part of the holds or machinery spaces. If, in order to comply with this requirement, an air hose exceeding 36,6 m (120 ft) in length would be necessary, a self-contained breathing apparatus is to be substituted or provided in addition.
- (2) A self-contained breathing apparatus which is to be capable of functioning for a period of at least 30 minutes. Spare bottles are to be provided except where facilities for re-charging the bottles are available on board ship.

Each breathing apparatus is to have attached to its belt or harness, by means of a snaphook, a fireproof lifeline of sufficient length and strength.

The safety lamp (hand lantern) is to be of an approved type. Such safety lamps are to be electric, and are to have a minimum burning period of three hours.

The axe is to have an insulated handle.

Closing of Openings and Control of Fans

336 Provision is to be made for closing all openings which might admit air to machinery spaces, to other spaces where there is risk of an oil fire and to cargo spaces protected by fire-smothering systems. Skylights and ventilators of machinery spaces including pump rooms in tankers are to be capable of being shut from deck or from a safe position outside these spaces. Provision is to be made for rapidly stopping all fans from positions outside such spaces.

Cross-references

337 For precautionary arrangements relating to oil leakage and outbreaks of fire, see:—

D 1926–D 1929, D 2113, D 2642, E 310, E 315–E 319, E 330–E 333, E 337–E 343, E 403–E 405, E 407, E 413–E 414, E 912 and E 1104.

Section 4

REQUIREMENTS FOR PASSENGER SHIPS

Fire Detection and Alarms

401 Manual fire alarms are to be fitted throughout the passenger and crew accommodation to enable the fire patrol to give an alarm immediately to the bridge or fire control station.

402 A fire alarm or fire detecting system is to be provided which will automatically indicate at one or more suitable points or stations, where it can be most quickly observed by officers and crew, the presence or indication of fire and its location in any parts of the ship such as cargo spaces, baggage and store rooms which are not accessible to the patrol system, except where the ship is engaged on voyages of such short duration that it would be unreasonable to apply this requirement.

Fire Pumps and Water Service Pipes

- 403 A passenger ship is to be provided with fire pumps, water service pipes, hydrants and hoses complying with F 2 and with the following requirements:—
 - (1) A passenger ship of 4000 tons gross and over is to be provided with at least three independently driven fire pumps and every passenger ship of less than 4000 tons gross with at least two such fire pumps.
 - (2) In a passenger ship of 1000 tons gross and over the arrangement of sea connections, pumps and sources of power for operating them is to be such as to ensure that a fire in any one compartment will not put all the fire pumps out of action.
 - (3) In a passenger ship of less than 1000 tons gross, if a fire in any one compartment could put all the pumps out of action, an emergency fire pump having a capacity of not less than 15 m³ (15 tons) per hour is to be provided.

Fire Hydrants, Hoses and Nozzles

- 404 A passenger ship is to be provided with such number of fire hoses as are appropriate and sufficient for the type of ship. There is to be at least one fire hose for each of the hydrants required by F 211, and these hoses are to be used only for the purposes of extinguishing fires or testing the fire extinguishing apparatus at fire drills and surveys.
- 405 In accommodation, service and machinery spaces, the number and position of hydrants are to be such that the requirements of F 211 may be complied with when all watertight doors and all doors in main vertical zone fire bulkheads are closed.
- 406 In a passenger ship the arrangements are to be such that at least two jets of water can reach any part of any cargo space when empty.
- 407 All hydrants in the machinery spaces of passenger ships with oil-fired boilers, steam turbine or internal combustion type propelling machinery are to be fitted with hoses having in addition to the nozzles required in F 215 nozzles

suitable for spraying water on oil, or alternatively, dual purpose nozzles. One such hydrant is to be provided in the shaft tunnel adjacent to the engine room watertight door.

International Shore Connection

408 A passenger ship of 1000 tons gross and over is to be provided with at least one international shore connection, complying with F 216. Facilities are to be available enabling such a connection to be used on either side of the ship.

Portable Fire Extinguishers in Accommodation and Service Spaces

409 A passenger ship is to be provided in accommodation, radio rooms and service spaces with such approved portable fire extinguishers as the Surveyors may deem to be appropriate and sufficient. In galleys and their sub-division, one or more portable extinguishers suitable for dealing with fires in oil-fired or electric cooking equipment are to be provided.

Fixed Fire-Smothering Arrangements in Cargo Spaces

- 410 The cargo spaces of passenger ships of 1000 tons gross and over are to be protected by a fixed fire-smothering gas system complying with F 3.
- 411 Where a passenger ship is engaged on voyages of such short duration that it would be unreasonable to apply the requirements of 410 and also in passenger ships of less than 1000 tons gross, the necessity for fire-smothering arrangements in cargo spaces will be specially considered.

Fire Extinguishing Appliances in Boiler Rooms, etc.

- 412 In spaces where main or auxiliary oil-fired boilers are situated, or in spaces containing oil fuel units or settling tanks, a passenger ship is to be provided with any one of the following fixed fire extinguishing installations complying with F 3:—
 - (1) A pressure water spraying system.
 - (2) A fire-smothering gas installation.
 - (3) A fixed froth installation supplemented, if necessary, by a fixed or mobile arrangement for pressure water or froth spraying to fight fire above the floor plates.

In each case if the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine room bilges, the combined engine and boiler rooms are to be considered as one compartment. 413 There are to be at least two approved portable extinguishers discharging froth or other approved medium suitable for extinguishing oil fires, in each firing space in each boiler room and each space in which a part of the oil fuel installation is situated.

There is not to be less than one approved froth type extinguisher of at least 136 litres (30 gallons) capacity or equivalent in each boiler room. These extinguishers are to be provided with hoses on reels suitable for reaching any part of the boiler room and spaces containing any part of the oil fuel installations.

414 In each firing space there is to be a receptacle containing at least 0,28 m³ (10 ft³) of sand, sawdust impregnated with soda or other approved dry material and a scoop for distributing this material. Alternatively, an approved portable extinguisher may be substituted therefor.

Fire Fighting Appliances in Spaces containing Internal Combustion Type Machinery

- 415 Where internal combustion engines or gas turbines are used, either (1) for main propulsion or (2) for auxiliary purposes associated with a total power not less than 1000 bhp, a passenger ship is to be provided with the following arrangements A and B:—
 - (A) There is to be one of the fixed arrangements 1, 2 or 3 required by 412.
 - (B) There is to be in each engine space one approved froth type extinguisher of not less than 45 litres (10 gallons) capacity or equivalent and also one approved portable froth type extinguisher for each 1000 bhp of the engines or part thereof; but the total number of portable extinguishers so supplied is not to be less than two and need not exceed six.

Fire Fighting Arrangements in Spaces containing Steam Machinery

416 Provision is to be made for extinguishing lubricating oil fires in spaces which are separated from boiler rooms by watertight bulkheads when these spaces contain steam turbines or enclosed forced lubricated steam engines using superheated steam. Equipment not less effective than detailed in 415 (B) is to be provided to the Surveyors' satisfaction.

Fireman's Outfits

417 A passenger ship is to carry at least two fireman's outfits each complying with the requirements of F 335.

Where the ship exceeds 10 000 tons gross at least three outfits are to be carried and where it exceeds 20 000 tons gross at least four outfits are to be carried. These outfits are to be kept in widely separated places ready for use.

Section 5

REQUIREMENTS FOR CARGO SHIPS

Fire Pumps and Water Service Pipes

501 All cargo ships are to be provided with fire pumps, water service pipes, hydrants and hoses complying in general with F 2.

- 502 In cargo ships of less than 150 tons gross, one power pump is to be available for fire extinguishing service. If the ship has a restricted class for harbour or river service a suitable hand pump may be substituted for the power pump.
- 503 In cargo ships of 150 tons gross and over, but less than 1000 tons gross, not less than two power pumps are to be provided, one of which is to be an independent pump.
- 504 In cargo ships of 1000 tons gross and over not less than two independently driven power pumps are to be provided.
- 505 In a cargo ship of 1000 tons gross and over if a fire in any one compartment could put all the pumps out of action there is to be an alternative means of providing water for fire fighting. This alternative means is to be a fixed emergency pump independently driven by a compression ignition engine, or other approved means and having a capacity of not less than 15 m3 (15 tons) per hour in ships of 1000 tons gross to 2000 tons gross, and not less than 25 m³ (25 tons) per hour for ships above 2000 tons gross. This emergency pump is to be capable of supplying two jets of water to the satisfaction of the Surveyors. The pump should be located remote from the machinery space, e.g., in ships with machinery amidships the pump should be installed in the tunnel or steering gear compartment, and in ships with machinery aft the pump preferably should be located forward. The pump is to be provided with its own sea suction and a discharge to the fire main. The suction lift is not to exceed 6 m (20 ft) with the ship in light draught. The fuel service tank for the engine is to have a capacity for at least 3 hours operation of the emergency pump. In addition sufficient fuel is to be available for at least 12 hours operation of this pump.

Fire Hydrants, Hoses and Nozzles

506 In cargo ships the number of fire hoses to be provided, each complete with couplings and nozzles, is to be one for each 30 m (100 ft) length of the ship and one spare, but in no case less than five in all for cargo ships of 1000 tons gross and over and three in all for smaller ships. These numbers do not include any hoses required in any engine or boiler room. If necessary the number of hoses is to be increased so as to ensure that hoses in sufficient number are available and accessible at all times, having regard to the type of the ship and the nature of the trade on which the ship is employed.

507 In accommodation, service and machinery spaces, the number and position of hydrants are to be such as to comply with the requirements of F 211. In a cargo ship the arrangements are to be such that at least two jets of water can reach any part of any cargo space when empty.

In ships of 2000 tons gross and over a hydrant is to be provided in the shaft tunnel adjacent to the engine room watertight door.

508 All hydrants in the machinery spaces of cargo ships with oil fired boilers or internal combustion type propelling machinery are to be fitted with hoses having in addition to the nozzles required in F 215 nozzles suitable for spraying water on oil, or alternatively, dual purpose nozzles.

International Shore Connection

509 A cargo ship of 1000 tons gross and over is to be provided with at least one international shore connection, complying with F 216. Facilities are to be available enabling such a connection to be used on either side of the ship.

Portable Fire Extinguishers in Accommodation and Service Spaces

510 A cargo ship is to be provided in accommodation, radio rooms and service spaces with a sufficient number of portable fire extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment of the crew and passenger spaces to the Surveyors' satisfaction; in any case, their number is not to be less than five for ships of 1000 tons gross and over and not less than three in ships of under 1000 tons gross.

For galleys and for spaces containing domestic boilers one portable fire extinguisher suitable for dealing with oil fires or fires in electric cooking equipment is to be provided.

Where a sprinkler system is installed the arrangements will be specially considered.

Fixed Fire-Smothering Arrangements in Cargo Spaces

511 Cargo spaces of ships of 2000 tons gross and over are to be protected by a fixed fire smothering system using carbon dioxide, inert gas or steam. The arrangements are to comply with F 3.

- 512 The requirements of 511 may be waived for the cargo holds of any ship (other than the tanks of a tanker):—
 - If they are provided with steel hatch covers having fireproof joints and effective means of closing all ventilators and other openings leading to the holds; or
 - (2) if the ship is constructed and intended solely for carrying such cargoes as ore, coal or grain; or
 - (3) where the ship is engaged on voyages of such short duration that it would be unreasonable to apply the requirement.
- 513 The cargo tanks of tankers of 500 tons gross and over are to be protected by a fixed fire smothering system using carbon dioxide, steam or froth. Installations discharging froth externally to the tanks may be accepted. The details of such installations are to be to the satisfaction of the Surveyors (for steam system see E 1119).
- 514 The cargo tanks of liquefied gas carriers are to be protected by a fixed fire smothering gas system and/or dry chemical extinguishing system. Details are to be submitted for approval.

Fire Detection in Cargo Spaces

515 A smoke or fire detection system is to be provided in each cargo space containing explosives and in adjacent cargo spaces.

Fire Extinguishing Appliances in Boiler Rooms, etc.

- 516 In spaces where main or auxiliary oil-fired boilers are situated, or in spaces containing oil fuel units or settling tanks, a cargo ship is to be provided with any one of the following fixed fire extinguishing installations complying with F 3.
 - (1) A pressure water spraying system.
 - (2) A fire-smothering gas installation.
 - (3) A fixed froth installation supplemented, if necessary, by a fixed or mobile arrangement for pressure water or froth spraying to fight fire above the floor plates.

The fixed installation is to be of type (2) above in all cases where the flash point of the oil fuel is less than 60°C (140°F) (closed cup test) or where methane gas is used as a fuel for the propulsion of methane tankers. See Chapter R (A).

In each case if the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine room bilges, the combined engine and boiler rooms are to be considered as one compartment.

517 There are to be at least two approved portable extinguishers discharging froth or other approved medium suitable for extinguishing oil fires in each firing space in each boiler room and each space in which a part of the oil fuel installation is situated. In addition, there is to be at least one extinguisher of the same description with a capacity of 9 litres (2 gallons) for each burner, provided that the total capacity of the additional extinguisher or extinguishers need not exceed 45 litres (10 gallons) for any one boiler room.

518 In each firing space there is to be a receptacle containing at least 0,28 m³ (10 ft³) of sand, sawdust impregnated with soda, or other approved dry material and a scoop for distributing this material. Alternatively, an approved portable extinguisher may be substituted therefor.

Fire Fighting Appliances in Spaces containing Internal Combustion Type Machinery

519 Where internal combustion engines or gas turbines are used, either (1) for main propulsion machinery, or (2) for auxiliary purposes associated with a total power not less than 1000 bhp, a cargo ship of 1000 tons gross and over is to be provided with the following arrangements A and B, and a cargo ship of under 1000 tons gross with arrangement B. For cargo ships of under 150 tons gross the provision of a 45 litre (10 gallon) extinguisher may be waived.

- (A) There is to be one of the fixed arrangements 1, 2 or 3 required by 516.
- (B) There is to be in each engine space one approved froth type extinguisher of not less than 45 litres (10 gallons) capacity or equivalent and also one approved portable froth extinguisher for each 1000 bhp of the engines or part thereof; but the total number of portable extinguishers so supplied is not to be less than two and need not exceed six.

Fire Fighting Arrangements in Spaces containing Steam Machinery

520 Provision is to be made for extinguishing lubricating oil fires in spaces which are separated from boiler rooms by watertight bulkheads when these spaces contain propulsion turbines or enclosed forced lubricated engines using superheated steam. Equipment not less effective than detailed in arrangement B of 519 is to be provided to the Surveyors' satisfaction.

Fire Fighting Arrangements in Pump Rooms and Compressor Rooms of Tankers

521 The cargo pump rooms in tankers of 500 tons gross and over are to be provided with a fixed, deck operated, fire extinguishing system using steam, water spray, carbon dioxide or other suitable medium.

In addition, two portable foam extinguishers or equivalent are to be provided, one at the pumps and one at the pump room entrance.

522 The cargo pump rooms and compressor rooms in liquefied gas carriers of 500 tons gross and over are to be provided with a fixed remote controlled fire extinguishing system using carbon dioxide or other suitable medium.

In addition, two portable dry chemical extinguishers or equivalent are to be provided in each space.

523 In tankers and liquefied gas carriers of less than 500 tons gross the fire extinguishing arrangements are to be to the satisfaction of the Surveyors.

Fireman's Outfits

524 A cargo ship is to carry at least one fireman's outfit complying with the requirements of F 335. Ships of 4000 tons gross and over are to carry two such outfits which are to be located at widely separated positions.

Section 6

REQUIREMENTS FOR SHIPS NOT FITTED WITH PROPELLING MACHINERY

601 A power pump or hand pump is to be fitted having a suction from the sea and a discharge to deck for fire extinguishing purposes.

Where oil fuel is used for the generation of power, fire extinguishing appliances suitable for fighting oil fires are to be provided to the satisfaction of the Surveyors.

PART 2

FIRE PROTECTION IN PASSENGER, CARGO AND OTHER SHIPS

Section 7

GENERAL

- 701 Except where otherwise stated, the requirements of Part 2 of this Chapter apply to passenger ships carrying more than 36 passengers, and cargo ships of 4000 tons gross and over, to be classed for unrestricted service.
- 702 While the requirements satisfy the regulations of the International Convention for the Safety of Life at Sea, 1960, attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered. Compliance with these statutory requirements may be accepted as meeting the requirements of this Chapter.
- 703 Consideration will be given to special cases where the arrangements are equivalent to those required by these Rules. Consideration will also be given to fire protection arrangements in ships to be classed for restricted or special services.
- 704 Plans showing the proposed arrangements are to be submitted for approval.

Materials

- 705 The hull, superstructures, bulkheads, decks and deckhouses are to be of steel or other material which, by itself or due to insulation provided, has structural and fire integrity properties equivalent to steel. In cargo ships the use of other suitable material will be specially considered.
- 706 Pipes conveying oil or combustible liquids are to be of approved material having regard to the fire risk. Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the water line and where the failure of the material in the event of fire would give rise to dangers of flooding.

Section 8

REQUIREMENTS FOR PASSENGER SHIPS CARRYING MORE THAN 36 PASSENGERS

Main Vertical Fire Zones and Fire Divisions

801 The hull, superstructures and deckhouses are to be sub-divided into main vertical fire zones, the mean length

of which on any one deck does not in general exceed 40 m (131 ft), by "A" Class fire-resisting divisions as defined in the Safety Convention. Steps and recesses are to be kept to a minimum and are to be of "A" Class divisions.

So far as practicable, the bulkheads forming the boundaries of the main vertical fire zones above the bulkhead deck are to be in line with watertight sub-division bulkheads situated immediately below. Such bulkheads are to extend from deck to deck and to the shell or other boundaries.

Openings in "A" Class Fire-Resisting Divisions

- 802 Where "A" Class divisions are pierced for electric cables, pipes, trunks, ducts, girders, beams, etc., arrangements are to be made to ensure that the fire resistance is not impaired.
- 803 Dampers are to be fitted in ventilation trunks and ducts passing through main vertical fire zone bulkheads and are to have local control capable of operation from both sides of the bulkhead. The operating positions are to be readily accessible and marked in red lettering. Indicators are to be fitted to show whether the dampers are open or shut.
- 804 Except for tonnage openings and hatches to cargo, store and baggage spaces, all openings are to be provided with permanently attached means of closing which are to be at least as effective for resisting fires as the divisions in which they are fitted. Where "A" Class divisions are pierced by tonnage openings the means of closure are to be steel plates.
- 805 Doors and door frames in "A" Class divisions, with the means of securing them closed, are to provide resistance to fire and to the passage of smoke and flame equivalent to that of the bulkheads in which the doors are situated. Watertight doors need not be insulated.

Each door is to be capable of being opened from each side of the bulkhead by one person only. Fire doors in main vertical zone bulkheads other than watertight doors, are to be of the self-closing type with simple and easy means of release from the open position. These doors are to be of approved type, and the self-closing mechanism is to be capable of closing the door against an inclination of 3,5 degrees opposing closure.

Bulkheads within Main Vertical Fire Zones

806 In ships in which Safety Convention Method I or III fire protection arrangement is adopted, and in which an automatic sprinkler system is not to be fitted, the enclosure bulkheads within accommodation spaces, other than those required to be "A" Class fire-resisting divisions, are to be constructed of "B" Class fire-retarding divisions as defined in the Safety Convention. The arrangement of fire-retarding divisions will be specially considered in relation to the method of fire protection adopted.

Accommodation spaces are halls, dining rooms, lounges and similar permanently enclosed spaces, corridors, lavatories, cabins, offices, crew's quarters, barber shops, isolated pantries and lockers and similar spaces.

Separation of Accommodation Spaces from Machinery, Cargo and Service Spaces

807 The boundary bulkheads and decks separating accommodation spaces from machinery, cargo and service spaces are to be "A" Class fire-resisting divisions, the insulating value of which will be specially considered having regard to the nature of the adjacent spaces.

Machinery spaces include all spaces used for propelling, auxiliary or refrigerating machinery, boilers, pumps, workshops, generators, steering gear, ventilation and air conditioning machinery, oil filling stations and similar spaces and trunks to such spaces.

Service spaces are galleys, main pantries, stores, (except isolated pantries and lockers), mail and specie rooms and similar spaces and trunks to such spaces.

Primary deck coverings within accommodation spaces, control stations, stairways and corridors are to be of approved material which will not readily ignite.

Protection of Stairways in Accommodation and Service Spaces

808 Stairways in accommodation and service spaces are to be of steel frame or other approved equivalent construction and are to be within enclosures formed of "A" Class divisions with positive means of closure at all openings from the lowest accommodation deck at least to a level which is directly accessible to the open deck, except that:—

- (1) a stairway connecting only two decks need not be enclosed, provided the integrity of the deck is maintained by proper bulkheads or doors at one level:
- (2) stairways may be fitted in the open in a public space, provided they lie wholly within such public space.

Stairway enclosures are to have direct communication with the corridors and are to be of sufficient area to prevent congestion having in view the number of persons likely to use them in an emergency, and are to contain as little accommodation, or other enclosed space in which a fire may originate, as practicable.

The insulation value of stairway enclosure bulkheads will be specially considered having regard to the nature of the adjacent spaces. The means for closure at openings in stairway enclosures are to be at least as effective for resisting fire as the bulkheads in which they are fitted. Doors other than watertight doors are to be of the self-closing type, as required for the main vertical fire zone bulkheads in accordance with 805.

The construction and protection of auxiliary stairways which do not form part of the general means of escape will be specially considered.

Protection of Lift Trunks, Light and Air Trunks, Control Stations and Storerooms, etc.

809 Passenger and service lift trunks, vertical trunks for light and air to passenger spaces, etc., are to be of "A" Class fire-resisting divisions. Doors are to be of steel or other equivalent material and when closed are to provide fire resistance at least as effective as the trunks in which they are fitted.

Lift trunks are to be so fitted as to prevent the passage of smoke and flame from one 'tween deck to another and are to be provided with means of closing so as to permit of draught and smoke control. Insulation need not be fitted to lift trunks which are within stairway enclosures.

Where a trunk for light and air communicates with more than one 'tween deck space and where smoke and flame are likely to be conducted from one 'tween deck to another, smoke shutters, suitably placed, are to be fitted so that each space can be isolated in case of fire.

Any other trunk (e.g., for electric cables) are to be so constructed as not to afford passage for fire from one 'tween deck or compartment to another.

810 Control stations are to be separated from the remainder of the ship by "A" Class bulkheads and decks.

Control stations are those spaces in which radio, main navigating or central fire-recording equipment or the emergency generator is located.

811 The boundary bulkheads of baggage rooms, mail rooms, store rooms, paint and lamp lockers, galleys and similar spaces are to be of "A" Class divisions. Spaces containing highly inflammable stores are to be so situated as to minimise the danger to passengers or crew in the event of fire.

Superstructures

812 Superstructures of aluminium alloy will be specially considered in relation to the Safety Convention Method of fire protection adopted. Where the use of aluminium alloy is approved:—

- Adequate provision is to be made to ensure that, in the event of fire, arrangements for stowage, launching and embarkation into lifeboats and rafts remain as effective as if the superstructures were constructed of steel; and
- (2) Crowns and casings of boiler and machinery spaces are to be of steel adequately insulated, and any openings therein suitably arranged and protected to prevent spread of fire.

See F 323.

Windows and Sidescuttles

813 All windows and sidescuttles in bulkheads separating accommodation spaces and the weather are to be constructed with metal frames. The glass is to be retained by a metal glazing bead.

814 In spaces containing main propulsion machinery, or oil-fired boilers, or auxiliary internal combustion type of machinery to total horsepower of 1000 or over, the following provisions are to be made:—

- (1) skylights are to be capable of being closed from outside the space.
- (2) skylights containing glass panels are to be fitted with external shutters of steel or other equivalent material permanently attached.
- (3) any windows in casings of such spaces are to be of non-opening type and are to be fitted with external shutters of steel or other equivalent material permanently attached.
- (4) in the windows and skylights referred to above, wire-reinforced glass is to be used.

Ventilation Systems

815 The main inlets and outlets of all ventilation systems are to be capable of being closed from outside the space in the event of fire. In general, the ventilation fans are to be so disposed that the ducts reaching the various spaces remain within the same main vertical zone.

816 All power ventilation, except cargo and machinery space ventilation, is to be fitted with master controls so that all fans may be stopped from either of two separate positions situated as far apart as practicable. Two master controls are to be provided for the power ventilation serving machinery spaces, one of which can be operated from a position outside the machinery space.

817 Efficient insulation is to be provided for exhaust ducts from galley ranges where the ducts pass through accommodation spaces.

Incombustible Materials

818 In ships in which Safety Convention Method I fire protection arrangement is adopted, and in which an automatic sprinkler system is not to be fitted, all linings, grounds, ceilings and insulations are to be of incombustible materials except in cargo spaces, mail rooms, baggage rooms, or refrigerated compartments of service spaces.

819 In ships in which Safety Convention Method III fire protection arrangement is adopted, and in which an automatic sprinkler system is not to be fitted, the use of combustible materials of all kinds such as untreated wood, veneers, ceilings, curtains, carpets, etc., is to be reduced as far as practicable. In large public spaces, the grounds and supports to the linings and ceilings are to be of steel or equivalent material. All exposed surfaces in corridors or stairway enclosures and concealed or inaccessible spaces shall have low flame-spread characteristics.

Automatic Sprinkler and Fire Alarm and Detection Systems

820 In ships in which Safety Convention Method II fire protection arrangement is adopted, and in which "B" Class fire-retarding divisions are not to be fitted within accommodation spaces, an automatic sprinkler and fire alarm system of an approved type, and complying with the requirements of F 317 to F 323, is to be installed and so arranged as to protect all enclosed spaces appropriated to the use or service of passengers or crew, except spaces which afford no substantial fire risk. See M 507.

Automatic Fire Alarm and Fire Detection Systems

821 In ships in which Safety Convention Method III fire protection arrangement is adopted and in which an automatic sprinkler is not to be fitted, a fire-detecting system of an approved type is to be installed and so arranged as to detect the presence of fire in all enclosed spaces appropriated to the use or service of passengers or crew (except spaces which afford no substantial fire risk), and automatically to indicate at one or more points or stations where it could be most quickly observed by officers and crew, the presence or indication of fire and also its location.

Miscellaneous Items

822 In all parts of the ship, paints, varnishes and similar preparations having a nitro-cellulose or other highly flammable base are not to be used.

823 In all parts of the ship, pipes penetrating "A" or "B" Class fire divisions are to be of approved material having regard to the temperature such fire divisions are required to withstand.

824 In accommodation and service spaces, air spaces enclosed behind ceilings, panellings or linings are to be suitably sub-divided by close-fitting draught stops not more than 13,7 m (45 ft) apart. In the vertical direction, such spaces, including those behind linings of stairways, trunks, etc., are to be closed at each deck. Small holes are to be arranged in ceilings and bulkheading, so that it will be possible, without impairing the efficiency of the fire protection, for the fire patrols to detect any smoke originating in concealed and inaccessible spaces. The concealed surfaces of all bulkheads, linings, panellings, stairways, wood grounds, etc., in accommodation spaces are to have low flame-spread characteristics.

Section 9

PASSENGER SHIPS CARRYING NOT MORE THAN 36 PASSENGERS

901 Passenger ships to be classed for unrestricted service and carrying more than 12 passengers but not more than 36 passengers need comply only with the fire protection requirements in F 705, F 706, F 801 to F 805, F 807, F 809 (first sub-paragraph), F 810 to F 815, F 822 and F 823.

902 In addition, the following provisions shall apply:—

- All stairways and means of escape in accommodation and service spaces shall be of steel or other suitable material.
- (ii) Power ventilation of machinery spaces shall be capable of being stopped from an easily accessible position outside the machinery spaces.
- (iii) Except where all enclosure bulkheads in accommodation spaces conform with the requirements in F 806, an automatic fire detection system conforming with F 402 is to be provided.

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Section 10

REQUIREMENTS FOR CARGO SHIPS OF OVER 4000 TONS GROSS

Corridor Bulkheads in Accommodation

1001 The corridor bulkheads in accommodation spaces are to be of steel or constructed of "B" class panels. The requirements of "B" class panels are specified in Chapter II Regulation 35 of the Safety of Life at Sea Convention 1960.

Protection of Interior Stairways, Lift Trunks, Galleys, Storerooms, etc.

1002 Interior stairways below the weather deck are to be of steel or other suitable material. Lift trunks within accommodation spaces shall be of steel or equivalent material. Bulkheads of galleys, paint stores, lamp rooms, boatswain's stores when adjacent to accommodation spaces and emergency generator rooms, if any, shall be of steel or equivalent material.

Deck Coverings

1003 Deck coverings within accommodation spaces on the decks forming the crown of machinery and cargo spaces shall be of a type which will not readily ignite.

Ventilation Systems

1004 Means shall be provided for stopping ventilating fans serving machinery and cargo spaces and for closing all doorways, ventilators, annular spaces around funnels and other openings to such spaces. These means shall be capable of being operated from outside such spaces in case of fire.

Paints, etc.

1005 In accommodation and machinery spaces, paints, varnishes and similar preparations having a nitro-cellulose or other highly flammable base are not to be used.

Section 11

REQUIREMENTS FOR CARGO SHIPS OF 500 TONS TO 4000 TONS GROSS

1101 F 1004 is to be complied with.

Chapter G

CONDITIONS FOR SURVEY OF MACHINERY DURING CONSTRUCTION

Section 1

GENERAL REQUIREMENTS

101 The materials used in the construction of the machinery, boilers and pressure vessels are to comply with the requirements of Chapter Q. Materials, for which provision is not made in Chapter Q, may be accepted after compliance with such tests as may be imposed, under specifications to be approved before the materials are ordered and construction is commenced.

The machinery, boilers and pressure vessels are to be inspected throughout, the boilers and pressure vessels tested by hydraulic pressure, and the machinery tested under full power working conditions by the Society's Engineer Surveyors, who will furnish a report to the Committee. If found satisfactory, the Committee will thereupon grant a certificate, and insert in the Register Book the appropriate class notation, as set forth in Chapter B, indicating that the machinery, boilers and pressure vessels are certified to have been in good order and safe working condition on that date.

102 In cases of machinery which has been built under Special Survey, the distinguishing mark & will be inserted before the appropriate class notation, as set forth in Chapter B.

103 In ships built under Special Survey, the following items of machinery are also to be constructed under Special Survey:—

The main and auxiliary engines and boilers, superheaters, economisers (including press boilers and similar apparatus for floating whale-oil factories), steering engines, air receivers, air compressors, scavenge blowers and superchargers, oil fuel burning units, feed pumps, circulating and cooling water pumps, fire and bilge pumps, air pumps, ballast and oil fuel transfer pumps, water extraction pumps, lubricating oil pumps, fuel valve cooling pumps for oil engines, forced and induced draught fans, evaporators, distiller units, feed water heaters and pressure filters where the foregoing are intended for essential services, domestic boilers intended for working pressures exceeding 3,5 kg/cm² (50 lb/in²) and having heating surfaces greater than 4,65 m² (50 ft²) and athwartship thrust units including prime movers and control mechanism.

Generators of 100 kW and over and motors of 100 hp and over intended for essential services.

Motors intended for coupling to fans for the circulation of air in refrigerated cargo spaces.

Electric slip couplings.

All electric propelling machinery including switchgear, control gear, cables, main and auxiliary generators, motor and exciters.

NOTE. Auxiliary boilers supply steam to auxiliary services essential to the operation of the ship at sea; but do not supply steam to the main propelling machinery.

Domestic boilers supply steam for purposes not connected in any way with the operation of the ship at sea.

104 In order to facilitate the inspection, plans in triplicate of the following items, together with the necessary particulars of the machinery, including the maximum power and the revolutions per minute, are to be submitted for consideration before the work is commenced:—

Boilers, superheaters and economisers.

Air receivers.

Crank, thrust, intermediate and screw shafting and screw shaft oil gland.

Clutch and reversing gear with methods of control and flexible coupling.

Reduction gearing. (See also H 302.)

Propeller (including spare propeller if supplied). (See also H 402.)

General arrangement of shafting showing relative positions of the main engines, flywheel, flexible coupling, gearing, thrust block, line shafting and bearings, stern tube, "A" bracket and propeller, whichever is applicable.

Torsional vibration calculations for the shafting systems. (See H 241 to H 243.)

Notes. Plans additional to the above should not be submitted unless the machinery is of a novel or special character affecting classification. For Plans of Pumping and Piping required to be submitted, see E 101.

For Steam Turbines, see H 802.

For Gas Turbines, see H 902.

For Welded Structures for Oil Engines, see H 702.

For Welded Pressure Vessels, see J 104.

For Control Engineering Equipment, see L 102.

For Electrical Equipment and Electric Propelling Machinery, see M 102.

For Refrigerated Cargo Installations, see N 202.

- 105 Where it is proposed to depart from the requirements of the Rules, the Committee will be prepared to give consideration to the circumstances of any special case.
- 106 Any novelty in the construction of the machinery boilers or pressure vessels is to be reported to the Committee.
- 107 The Surveyors are to examine and test the materials and workmanship from the commencement of the work until the final test of the machinery under full power working conditions; any defects, etc., are to be pointed out as early as possible.
- 108 Where items of machinery are to be manufactured under batch or line production procedures, making normal survey methods difficult or inapplicable, the Committee will be prepared on application to give consideration to the adoption of an alternative system of examination, involving periodical inspection of the works instead of survey of each individual item.

In order to obtain approval, the requirements of G 2 are to be complied with.

- 109 The Surveyors may also, if requested, compare the work as it progresses with the requirements of the specification agreed upon by the parties concerned, and certify to the conditions thereof, so far as can be seen, being satisfactorily complied with.
- 110 The machinery and boilers are to be securely fixed to the ship's structure to the satisfaction of the Surveyor. The bed plates, gear cases, thrust blocks and boiler fastenings are to be of robust construction.
- 111 Refrigerating machinery using a toxic or flammable refrigerant, such as ammonia, is to be installed in an efficiently ventilated compartment isolated from the propelling machinery spaces and shaft tunnels, and living quarters.

Methyl chloride refrigerant is not to be used.

Machinery using non-toxic and non-flammable refrigerants will not be subject to restriction on location in general, but proposals to install relatively large plants in propelling machinery spaces will require special consideration.

Cross-references

112 For conditions relating to the survey during construction of Electrical Equipment, Electrical Propelling Machinery and Refrigerating Machinery and Appliances, see M 1, M 17 and N 1 respectively.

Section 2

CERTIFICATION OF BATCH AND LINE PRODUCED MACHINERY

General

- 201 The system for the certification of batch and line produced machinery is applicable to items of equipment produced in circumstances which would make the individual survey at all stages of manufacture impractical.
- 202 The Committee will consider the proposed design for compliance with the Society's Rules, or other appropriate requirements, and the extent to which the manufacturing processes and control procedures ensure conformance of the product to the design.
- 203 Where the Committee consider that the requirements of 202 can be satisfactorily complied with, the manufacturers will, in general, be authorized to inspect and certify their products.

For products which require individual certification by the Society's Surveyors, delegation will be limited to certain preliminary aspects of manufacture. In the course of construction, the Surveyors are to examine and test such products and issue the final certificate.

204 The procedures and practices of manufacturers which have been granted approval, will be kept under continuous review.

Qualification for Approval

205 The manufacturer is required to demonstrate a clearly defined management structure.

The Quality Control Manager or Chief Inspector is to be acceptable to the Committee and should be responsible to management without being subject to the pressures of production output.

206 There is to be an efficient system for the control of drawings and technical data to ensure that all departments are working to the latest design information.

- 207 The manufacturer is to be responsible for ensuring that all supplies and services procured from suppliers and sub-contractors are of adequate quality and conform to the Society's requirements. The Committee reserves the right to inspect, at source, any supplies manufactured by sub-contractors.
- 208 The arrangements for the handling, transportation and storage of material and components should ensure that such items are not adversely affected and, at all times, bear sufficient indication of identity and status.
- 209 The manufacturer should follow a policy for recruitment and training which provides an adequate labour force with such skills as are required for each type of work operation. There should be adequate supervision to ensure that standards of workmanship are maintained.
- 210 The quality control/inspection department should be staffed and equipped adequately to implement the quality control programme.
- 211 The manufacturer is to provide and maintain adequate and effective measuring and testing devices which are to be calibrated against certified measurement standards at established periods to assure continued accuracy.
- 212 The manufacturer is to operate a quality control programme appropriate to the product design and manufacturing techniques, which will ensure adequate quality standards at all stages of production, including sub-contracted work. The programme is to provide for the ready detection of discrepancies and for timely and effective corrective action.
- 213 The manufacturer is to maintain adequate records of supplies and services indicating the materials, deliveries, acceptances and rejections, so that variations in the quality of supplies and services can be readily observed by the Surveyors.
- 214 An effective system is to be maintained for the control of non-conforming material, including procedures for its identification, segregation and disposal. There should be adequate procedures for the repair, rework or disposal of non-conforming materials and components.
- 215 Records of inspection and test are considered to be one of the principal forms of objective evidence of quality, and these are to be complete and reliable. These records are to be available for review by the Society's Surveyors, and copies of individual records are to be furnished to the Surveyors on request.
- 216 Statistical quality control methods may be used, where suitable, to maintain control of quality. Wherever

possible, these methods should be based on established procedures.

Survey of Works

- 217 The Society's Surveyors will assess the manufacturing processes and control procedures of manufacturers applying for approval. The procedures employed are to be sufficiently documented to allow appraisal by the Surveyors.
- 218 Gauging, measuring and testing devices are to be made available to the Surveyors and, where appropriate, personnel for the operation of such devices.
- 219 The Surveyors will not specify in detail the procedures to be employed, but will consider the arrangements proposed by the manufacturer in relation to process and product. However, they may advise a manufacturer how the quality control programme might be improved.

In the event of procedures being considered inadequate, the Surveyors will advise the manufacturer how such procedures may be revised to be acceptable to the Society.

220 Approval by another organization will not be accepted as sufficient evidence that a manufacturer's arrangements comply with the Society's requirements.

Approval of Works

- 221 A certificate will be issued to each Approved Works indicating the products for which approval has been granted. The certificate will be valid for one year and renewal will be subject to satisfactory re-survey.
- 222 Manufacturers may obtain extension of approval in respect of further products of their own manufacture, at the discretion of the Committee without additional survey of their works.
- 223 The Society will publish a list of manufacturers whose works have been approved and are under continuous survey.

Product Certification

224 Nominated personnel of the manufacturer will be authorized to certify that the product conforms to its design specification and to the requirements of Lloyd's Register of Shipping.

Continuous Review Arrangements

225 The quality control arrangements of an Approved Works will be kept under continuous review and the whole of the manufacturer's activities in this respect are to be open to periodical and systematic surveys by the Surveyors

at all reasonable times. The Surveyors will indicate immediately to the Quality Control Manager, or Chief Inspector, any matter with which they are not satisfied.

- 226 The Society's Surveyors will visit the Works at intervals determined by the nature of the product, rate of production and standard of quality control arrangements.
- 227 In the event of noteworthy departures from the drawing or specification being accepted, a standard "Concession" form is to be completed and signed by both the Design Manager and the Quality Control Manager, or their authorized deputies. In all cases where strength or functioning may be affected, the form is to be submitted to the
- 228 Maintenance of approval will be subject to the

Surveyors for approval and endorsement.

continuance of those details of supplies, organization,

15th July, 1971

procedures and methods which formed the basis for granting approval. Where changes are proposed, the attending Surveyors are to be advised in order that consideration can be given to such changes.

229 When appropriate, the Surveyors may apply intensive supervision, possibly including a degree of direct inspection.

Suspension or Withdrawal of Approval

- 230 When the Surveyors are satisfied that a fault or deficiency in the manufacturer's arrangements, previously pointed out, has not been rectified in a reasonable time, the manufacturer will be notified, in writing, of the Committee's intention to suspend approval.
- 231 When approval has been suspended and the manufacturer has proved unable or unwilling to take corrective action, approval will be withdrawn.

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Chapter H

MAIN AND AUXILIARY ENGINES AND ASSOCIATED MACHINERY COMPONENTS

Scope

The requirements of this Chapter are applicable to main and auxiliary engines including oil engines, steam and gas turbines, gearing and other associated machinery components.

The main and auxiliary engines are to be made in accordance with the requirements contained in the following Sections, where applicable:—

Section 1 General Requirements,

- ,, 2 Shafting for Oil Engine, Turbine and Electric Propulsion Installations,
- ,, 3 Reduction Gearing for Propelling and Auxiliary Engines,
- ,, 4 Propellers,
- " 5 Strengthening for Navigation in Ice,
- ,, 6 General Requirements for Oil Engines and Starting Air Compressors,
- ,, 7 Welded Structures for Oil Engines,
- ,, 8 General Requirements for Steam Turbines,
- , 9 General Requirements for Gas Turbines.

Note. For steam reciprocating engines, with or without exhaust steam turbines, the appropriate requirements of the Society's Rules for Steel Ships 1969 are to be complied with.

Section 1

GENERAL REQUIREMENTS

Materials

101 Materials for crank shafts, turbine rotors, pinions gear wheels, shafts including line shafting, propellers and other important machinery parts are to be made and tested under the supervision of the Surveyors in accordance with the appropriate requirements of Chapter Q or, in special cases, with an approved specification.

102 Where it is proposed to use non-ferrous metal for shafting, details of the specification and method of manufacture are to be submitted for consideration.

Inspection

103 The surfaces of shafting and other important machinery parts are to be examined when finish machined and, if required by the Surveyors, also in the rough machined condition.

Definitions

104 Where horse power appears in this Chapter it is to be taken as 76 kg m (550 ft lb) per second.

Operating Conditions and Power Ratings

- 105 In the Sections in this Chapter where the dimensions of any particular component are determined on horse power and revolutions per minute, denoted by H and R respectively, the appropriate values to be used in the relevant formulæ are to be derived from the following:—
 - (a) For main propelling machinery, the maximum propulsion shaft or brake horse power and corresponding revolutions per minute for which the machinery is to be classed.
 - (b) For auxiliary machinery, the maximum continuous shaft or brake horse power and corresponding revolutions per minute which will be used in service.
- 106 The rating of main and essential auxiliary machinery intended for installation in sea-going ships to be classed for unrestricted (geographical) service should be based on a sea temperature not less than 30°C (86°F) and an engine room ambient temperature not less than 45°C (113°F). In the case of ships to be classed for restricted service, the rating should be suitable for the temperature conditions associated with the geographical limits of the restricted service. See B 109 and B 110.

107 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and in the case of oil engines of developing for a short period (15 min) an overload power of not less than 10 per cent (see M 106, M 403 and M 404).

Enginebuilders should satisfy the Surveyors by tests on individual engines that the above requirements, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in 106. Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests, e.g., against a brake, representing a particular size and range of engines may be accepted. With oil engines and gas turbines, any fuel stop fitted should be set so as to permit the short period overload power of not less than 10 per cent above full rated output (kW) being developed.

Alignment Gauges and Wear Down Gauges

108 All main and auxiliary oil engines exceeding 300 bhp are to be provided with an alignment gauge which may be either a bridge wear down gauge, or a micrometer clock gauge for use between the crank webs. Only one micrometer clock gauge need be supplied for each ship provided the gauge is suitable for use on all engines.

Main and auxiliary turbines are to be provided with bridge wear down gauges for testing the alignment of the rotors.

Reduction gears with sleeve bearings, for main and auxiliary turbines and oil engines, are to be provided with bridge wear down gauges for testing the internal alignment of the various elements in the gear cases. In certain gears, e.g., gears of the locked train type, the direction of loading on the bearings of a gear element may be such that an accurate indication of its alignment under operating conditions cannot be obtained using the bridge type wear down gauge. In these instances, suitable alternatives such as crown thickness micrometers are to be provided.

The Surveyors are to witness the initial readings of the wear down gauges.

In the case of reduction gearing for main turbines and oil engines, also for auxiliary turbines and oil engines exceeding 300 shp, trammels or other approved means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gear case has taken place, when chocked and secured to its seating on board ship.

Cross-references

109 For means of escape from machinery spaces and communication between bridge and engine room, see D 2113 and D 2114.

Section 2

SHAFTING FOR OIL ENGINE, TURBINE AND ELECTRIC PROPULSION INSTALLATIONS

General

The requirements of this Section relate, in particular, to formulæ for determining the diameters of shafting for main propulsion and auxiliary machinery installations but requirements for torsional vibrations, couplings, coupling bolts, keys, keyways, stern bushes and other associated components are also included.

The Section is divided into three parts as follows:-

- Part 1 Crank Shafts for Oil Engines.
 Paragraph Nos. 201 to 208.
- Part 2 Gear and Line Shafting and Associated Components for Oil Engine, Turbine and Electric Propulsion Installations.
 - Paragraph Nos. 221 to 236.
- Part 3 Torsional Vibrations.

 Paragraph Nos. 241 to 243.

PART 1

CRANK SHAFTS FOR OIL ENGINES

Material

- 201 Material specifications for steel crank shafts, forging procedures and heat treatment details are to be submitted.
- 202 Where it is proposed to make crank shafts of cast iron, the material specification and the dimensions of the shaft are to be submitted for special consideration.

The material specification should state the type of cast iron, the heat treatment, and mechanical properties, including the specified minimum tensile strength appropriate to the section of the crank shaft casting.

Any suitable type of high duty cast iron may be used, provided the minimum specified tensile strength is between 32 and 76 kg/mm² (20 and 48 ton/in²). Crank shafts are to be cast at a foundry approved for the production of cast iron crank shafts and are to be in accordance with Q 8.

Crank Shafts

203 For steel crank shafts of solid forged, cast, semibuilt and built construction, also for cast iron crank shafts, the power rating of the engine is not to exceed that given by the following formula:—

$$\frac{H_{0}}{R_{0}} = \frac{nE}{5810 \text{ CK}_{1}} \left[\frac{d^{3} Z (T+16)}{7000} - \frac{AK_{2} P (l-l_{p}) D^{2}}{100 000} \right]$$

or in British units:-

Note. The power rating $\frac{H_0}{R_0}$ is not to be less than the power rating based on H and R as defined in H 105.

where $H_0 = \text{maximum}$ designed brake horse power,

 R_o = revolutions per minute of the crank shaft at maximum designed brake horse power,

n = number of cylinders for 2SCSA engines,

 half the number of cylinders for 4SCSA engines,

E = mechanical efficiency of the engine expressed as a decimal,

A and C = coefficients from Tables H 2.1, H 2.2, H 2.3 or H 2.4 for appropriate cycle and firing order with equal intervals between firing (cylinders numbered from the free end of the engine),

 $K_1 = 0.8 + \frac{u}{3 d_p} + 0.243 \sqrt{\frac{d_p}{r}}$ for solid forged steel or cast iron crank shafts and the combined pins and webs of semi-built forged or cast steel crank shafts,

K₁ = 1,8 for shrunk sections of forged or cast steel semi-built and built crank shafts,

d_p = diameter of crank pin, in mm (in),

r = fillet radius at junction of crank web with crank pin, in mm (in). (The fillet radius at junction of journal and crank web is not to be less than r),

 $u = d_p + d_j - S$

diameter of crank journal, in mm (in),

S = length of stroke, in mm (in),

d = minimum diameter of crank shaft pin or journal, whichever is less, or equivalent diameter for hollow shafting, in mm (in),

Z = 1,0 except as follows:-

= 1,15 for die-forged crank shafts and continuous grain-flow crank shafts where these methods of manufacture or processing have been specially approved,

= 1,25 for crank shafts surface-hardened by nitriding where full particulars of the method and process have been approved. (Note. Special consideration will be given to other surface-hardening treatments which include the fillet radii, in allocating an appropriate Z value. If it can be proved that any surface-hardening process will further improve the fatigue characteristics of die-forged or continuous grain flow crank shafts, consideration will be given to the use of a combined Z value),

$$=rac{ extsf{T} + 26,5 - 0,006 ext{ d}}{1,23 extsf{(T} + 16)}$$

$$\left(=\frac{\mathsf{T}+16.7-0.1\,\mathsf{d}}{1.23\,(\mathsf{T}+10)}\,\mathsf{British}\right)$$

for cast iron crank shafts.

T = specified minimum tensile strength of crank shaft material, in kg/mm² (ton/in²),

K₂ = 7,0 for shrunk sections of forged or cast steel semi-built and built crank shafts,

 $\mathsf{K_2} = \mathsf{Q}\,\mathsf{F}\,\mathsf{G}\sqrt{\frac{\mathsf{d}_p}{r}}\,\mathsf{for}\;\mathsf{solid}\;\mathsf{forged}\;\mathsf{steel}\;\mathsf{or}\;\mathsf{cast}$

iron crank shafts and the combined pins and webs of semi-built forged or cast steel crank shafts,

Q = coefficient from Fig. H 2.1,

(Note. Q is to be taken as 1,0 for all negative values of $\frac{u}{d_D}$ greater than 0,6),

m = depth of recess of fillet into crank web, in mm (in),

F = coefficient from Fig. H 2.2,

b = breadth of web, in mm (in),

G = coefficient from Fig. H 2.3 or Fig. H 2.4,

t = axial thickness of web, in mm (in),

P = maximum combustion pressure, in kg/cm² (lb/in²), at maximum designed brake horse power,

l = span of bearings adjacent to a crank measured from inner edge to inner edge, in mm (in),

 $l_{\rm p} = \text{length of crank pin, in mm (in),}$

D = diameter of cylinder, in mm (in).

Engines having unequal firing intervals or not covered by values of A and C given in Tables H 2.1, H 2.2, H 2.3 or H 2.4 and Vee engines having different firing orders on each bank will receive special consideration.

For Vee engines having minimum firing intervals between two cylinders on one pin different from those given in Tables H 2.3 or H 2.4, the values of A and C may be obtained by interpolation.

204 In designs of crank shafts to which the engine power rating formula in 203 is not directly applicable, detailed design calculations are to be submitted for special consideration.

205 Special consideration will be given to cast iron crank shafts which have been designed and developed for optimum fatigue strength with cranks of the most favourable shape, and some allowance made for the superior strength thereby obtained. Particulars of any relevant tests or experience should be submitted.

Crank Webs of Built and Semi-built steel Shafts

206 Where the crank webs are shrunk on crank pins or journals, the dimensions and yield stress of the material of the crank webs are not to be less than given by the following formulæ for the shrinkage allowance proposed:—

$$\begin{split} t &= \frac{d_{r}^{3} (d_{o} + 2 h)^{2}}{6250 S_{1} k d_{o} h (d_{o} + h)} \, \text{mm (in)} \\ f_{y} &= 9400 S_{2} \frac{k}{d_{o}} \left[1 + \left(\frac{d_{o}}{d_{o} + 2 h} \right)^{2} \right] \, \text{kg/mm}^{2} \\ \left(f_{y} &= 5970 S_{2} \frac{k}{d_{o}} \left[1 + \left(\frac{d_{o}}{d_{o} + 2 h} \right)^{2} \right] \, \text{ton/in}^{2} \right) \end{split}$$

where t = axial thickness of web which is not to be less than 0.525 d_{r.} in mm (in),

G_r = minimum diameter of crank shaft determined by 203 using K₁ = 1,8, K₂ = 7,0, Z = 1,0 and T = 44 kg/mm² (28 ton/in²) for the proposed power rating, in mm (in),

do = diameter of hole in crank web, in mm (in),

h = radial thickness of metal around hole in crank web, in mm (in),

S₁ = minimum shrinkage allowance at pins or journals, in mm (in),

S₂ = maximum shrinkage allowance at pins or journals, in mm (in),

k = 1 for solid pins or journals or as determined from Fig. H 2.5 for pins or journals with central holes,

d_i = diameter of holes in pins or journals, in mm (in),

f_y = specified minimum yield stress of the material of the crank web, in kg/mm² (ton/in²).

207 Reference marks are to be provided on the outer junction of the crank webs with the crank pins and journals.

Fillets and Oil Holes

208 Fillets at the junctions of crank webs with crank pins or journals, where these are formed as solid forgings or castings, are to have a smooth finish.

Oil holes at the surfaces of crank pins and journals are to be rounded to an even contour with a smooth finish.

TABLE H 2.1
CRANK SHAFT COEFFICIENTS A AND C FOR 2SCSA ENGINES

No. of	FIRING ORDER FROM FREE END OF ENGINE	FORWAR	D FIRING	REVERSE FIRING		
CYLS.	(Equal Intervals)	A	C	A	C	
2	1-2	0,41	2,5	0,41	2,5	
3	1-2-3	0,38	3,9	0,38	3,9	
4	1-2-3-4 1-2-4-3 1-3-2-4	0,36 0,36 0,36	4,5 4,5 4,6	0,36 0,36 0,36	4,5 4,5 4,6	
5	1-2-4-5-3 1-2-5-3-4 1-3-5-2-4 1-4-3-2-5	0,34 $0,36$ $0,35$ $0,35$	5,4 4,9 5,0 5,0	0,34 0,36 0,35 0,35	5,4 4,9 5,1 5,0	
6	1-3-5-2-4-6 1-4-2-6-3-5 1-4-3-5-2-6 1-4-5-2-3-6 1-5-3-4-2-6	0,36 0,38 0,38 0,36 0,38	5,0 3,9 3,9 5,0 3,9	0,37 0,38 0,38 0,37 0,38	4,3 3,9 3,9 4,3 3,9	
7	$\begin{array}{c} 1-4-6-2-5-3-7 \\ 1-4-7-2-3-5-6 \\ 1-5-2-6-4-3-7 \\ 1-5-3-6-2-4-7 \\ 1-5-4-6-2-3-7 \\ 1-6-3-4-5-2-7 \\ 1-6-3-5-4-2-7 \end{array}$	0,38 0,35 0,37 0,38 0,37 0,37 0,37	3,7 5,3 4,4 3,6 4,3 4,4 4,4	0,35 0,35 0,37 0,35 0,35 0,37 0,37	5,4 5,4 4,4 5,4 5,0 4,4 4,4	
8	$\begin{array}{c} 1-5-4-7-2-6-3-8 \\ 1-5-6-2-7-3-4-8 \\ 1-5-8-2-4-7-3-6 \\ 1-6-3-7-2-5-4-8 \\ 1-6-3-8-2-5-4-7 \\ 1-6-4-2-7-3-5-8 \\ 1-6-4-2-8-3-5-7 \\ 1-6-4-7-2-5-3-8 \\ 1-6-5-2-7-4-3-8 \\ 1-6-5-2-8-3-4-7 \\ 1-7-2-5-4-6-3-8 \\ 1-7-3-4-6-5-2-8 \\ 1-7-3-5-4-6-2-8 \\ 1-7-3-5-4-6-2-8 \\ 1-7-4-3-6-5-2-8 \end{array}$	0,34 0,35 0,35 0,34 0,34 0,35 0,35 0,35 0,35 0,35 0,32 0,32 0,32	5,8 5,5 5,8 5,8 5,2 5,2 5,2 5,2 6,7 6,7 6,7	0,34 0,35 0,35 0,34 0,35 0,35 0,35 0,35 0,35 0,32 0,32 0,32 0,32	5,8 5,5 5,8 5,8 5,2 5,2 5,2 6,7 6,7 6,7	
9	$\begin{array}{c} 1\text{-}4\text{-}9\text{-}2\text{-}5\text{-}7\text{-}3\text{-}6\text{-}8 \\ 1\text{-}4\text{-}9\text{-}7\text{-}2\text{-}3\text{-}6\text{-}8\text{-}5 \\ 1\text{-}5\text{-}7\text{-}3\text{-}8\text{-}2\text{-}6\text{-}4\text{-}9 \\ 1\text{-}5\text{-}9\text{-}2\text{-}4\text{-}7\text{-}3\text{-}6\text{-}8 \\ 1\text{-}6\text{-}7\text{-}2\text{-}6\text{-}8\text{-}3\text{-}4\text{-}9 \\ 1\text{-}6\text{-}7\text{-}3\text{-}4\text{-}9\text{-}2\text{-}5\text{-}8 \\ 1\text{-}6\text{-}7\text{-}3\text{-}5\text{-}8\text{-}2\text{-}4\text{-}9 \\ 1\text{-}6\text{-}8\text{-}2\text{-}5\text{-}7\text{-}3\text{-}4\text{-}9 \\ 1\text{-}6\text{-}8\text{-}2\text{-}5\text{-}7\text{-}3\text{-}4\text{-}9 \\ 1\text{-}7\text{-}5\text{-}3\text{-}9\text{-}2\text{-}6\text{-}4\text{-}8 \\ 1\text{-}8\text{-}3\text{-}6\text{-}5\text{-}4\text{-}7\text{-}2\text{-}9 \\ \end{array}$	0,33 0,35 0,35 0,33 0,33 0,33 0,33 0,33	6,6 6,1 5,1 6,6 6,6 6,6 6,6 6,6 6,6 5,1 6,8	0,33 0,35 0,35 0,33 0,33 0,33 0,33 0,33	6,6 6,1 5,1 6,6 6,6 6,6 6,6 6,6 5,1 6,8	
10	$\begin{array}{c} 1-5-9-3-4-8-7-2-6-10 \\ 1-6-4-9-3-8-2-7-5-10 \\ 1-6-5-9-2-8-3-7-4-10 \\ 1-6-9-2-5-10-3-4-7-8 \\ 1-6-9-2-5-10-4-3-8-7 \\ 1-6-10-2-4-9-5-3-7-8 \\ 1-7-3-9-5-6-2-8-4-10 \\ 1-7-6-3-9-2-8-5-4-10 \\ 1-7-8-3-4-10-2-6-5-9 \\ 1-7-9-2-4-10-3-5-6-8 \\ 1-8-4-7-2-10-3-6-5-9 \\ 1-8-5-4-9-2-7-6-3-10 \\ 1-8-5-6-3-10-2-7-4-9 \\ 1-8-5-7-2-10-3-6-4-9 \\ 1-9-3-7-5-6-4-8-2-10 \\ 1-9-4-5-8-3-6-7-2-10 \\ \end{array}$	0,31 0,33 0,33 0,31 0,31 0,33 0,34 0,32 0,32 0,33 0,34 0,33 0,33 0,31 0,31	7,6 6,3 6,3 7,6 7,6 6,3 5,9 6,7 6,7 6,2 5,9 6,1 6,2 7,6	0,31 0,33 0,33 0,32 0,32 0,32 0,33 0,32 0,33 0,32 0,33 0,32 0,33 0,33	7,6 6,2 7,4 7,1 7,4 6,3 6,9 6,3 7,4 6,1 6,9 6,2 7,6	
11	$\begin{array}{c} 1 - 9 - 5 - 7 - 3 - 11 - 2 - 8 - 6 - 4 - 10 \\ 1 - 9 - 6 - 4 - 10 - 2 - 8 - 5 - 7 - 3 - 11 \\ 1 - 10 - 3 - 8 - 6 - 5 - 7 - 4 - 9 - 2 - 11 \end{array}$	0,34 0,32 0,30	6,1 7,2 8,3	0,34 0,31 0,30	6,0 7,9 8,3	
12	$\begin{array}{c} 1-4-8-12-3-5-7-10-2-6-9-11\\ 1-5-11-9-2-4-12-7-3-6-10-8\\ 1-5-12-7-2-6-10-8-3-4-11-9\\ 1-6-8-10-3-5-7-12-2-4-9-11\\ 1-6-11-7-3-5-10-9-2-4-12-8\\ 1-8-6-10-2-9-4-11-3-5-7-12\\ 1-8-6-10-2-9-4-11-3-7-5-12\\ 1-9-5-10-3-8-4-12-2-7-6-11\\ 1-10-5-7-9-2-12-3-8-6-4-11 \end{array}$	0,34 0,32 0,32 0,34 0,32 0,31 0,31 0,31 0,33	5,8 7,0 7,0 5,8 7,0 8,3 8,3 8,3 8,2 6,8	0,32 0,32 0,31 0,32 0,33 0,31 0,31 0,31 0,33	7,0 7,1 8,3 7,0 6,5 8,3 8,3 8,3 6,8	

TABLE H 2.2

CRANK SHAFT COEFFICIENTS A AND C FOR 4SCSA ENGINES

No. of	FIRING ORDER FROM FREE END OF ENGINE	FORWARI	FIRING	REVERSE FIRING		
CYLS.	(Equal Intervals)	A	C	A	C	
2	1-2	0,43	2,5	0,43	2,5	
3	1-2-3	0,41	3,2	0,41	3,2	
4	1-2-3-4 1-2-4-3	0,42 0,42	2,8 2,8	0,42 0,42	2,8 2,8	
5	1-2-4-5-3 1-4-3-2-5	0,38 0,38	4,5 4,7	0,38 0,38	4,6 4,6	
6	1-2-3-6-5-4 1-2-4-6-3-5 1-2-4-6-5-3 1-2-5-6-4-3 1-4-2-6-3-5	0,41 0,40 0,41 0,41 0,40	3,4 3,9 3,4 3,4 3,9	0,41 0,40 0,41 0,41 0,40	3,4 3,9 3,4 3,4 3,9	
7	1-2-4-6-7-5-3	0,37	5,0	0,37	5,1	
8	$\begin{array}{c} 1-2-3-5-8-7-6-4 \\ 1-2-4-6-8-7-5-3 \\ 1-2-5-6-8-7-4-3 \\ 1-3-2-4-8-6-7-5 \\ 1-3-2-5-8-6-7-4 \\ 1-3-5-2-8-6-4-7 \\ 1-3-7-4-8-6-2-5 \\ 1-4-6-2-8-5-3-7 \\ 1-4-7-3-8-5-2-6 \\ 1-5-2-6-4-8-3-7 \\ 1-5-3-2-8-4-6-7 \\ 1-5-7-3-8-4-2-6 \\ 1-6-4-2-8-3-5-7 \end{array}$	0,38 0,38 0,38 0,39 0,39 0,37 0,37 0,37 0,37 0,37 0,37 0,37	4,9 4,9 4,4 4,4 5,2 4,9 5,2 5,2 5,2 5,2 5,2	0,38 0,38 0,39 0,39 0,37 0,37 0,37 0,37 0,37 0,37 0,37	4,9 4,9 4,9 4,4 4,4 5,2 4,8 5,2 4,5 5,2 5,2 5,2 5,2 5,2	
9	1-2-4-6-8-9-7-5-3 1-4-2-3-7-8-6-9-5 1-4-7-2-6-9-3-5-8 1-5-9-3-6-8-2-4-7 1-5-9-3-7-8-2-4-6	0,37 0,37 0,37 0,37 0,37	5,5 4,9 5,3 5,3 5,3	0,37 0,37 0,37 0,37 0,37	5,5 5,4 5,3 5,3 5,3	
10	$\begin{array}{c} 1\text{-}4\text{-}3\text{-}2\text{-}5\text{-}10\text{-}7\text{-}8\text{-}9\text{-}6\\ 1\text{-}4\text{-}8\text{-}2\text{-}5\text{-}10\text{-}7\text{-}3\text{-}9\text{-}6\\ 1\text{-}6\text{-}2\text{-}8\text{-}4\text{-}10\text{-}5\text{-}9\text{-}3\text{-}7\\ 1\text{-}6\text{-}9\text{-}3\text{-}4\text{-}10\text{-}5\text{-}2\text{-}8\text{-}7\\ \end{array}$	0,37 0,37 0,37 0,36	5,1 5,4 5,4 5,8	0,37 0,37 0,36 0,35	5,2 5,4 5,4 5,8	
12	1-3-8-11-9-7-12-10-5-2-4-6 1-9-2-7-4-8-6-10-5-12-3-11	0,35 0,37	6,3 5,7	0,35 0,37	6,3 5,7	

TABLE H 2.3 CRANK SHAFT COEFFICIENTS A AND C FOR 2SCSA VEE ENGINES

No.	FIRING ORDER PER BANK	FIRING INTERVAL BETWEEN TWO CYLINDERS ON ONE PIN											
OF CYLS.	FROM FREE END OF ENGINE	36	6°	45°		50°		63,5°		90°			
	(Equal Intervals)	A	C	A	C	A	C	A	C	A	C		
4	1–2	0,64	3,6	0,55	3,7	0,54	3,7	0,53	3,6	0,53	3,8		
6	1-2-3	0,61	4,9	0,52	4,9	0,52	5,0	0,50	5,3	0,50	5,7		
	1-3-2	0,61	5,0	0,52	5,3	0,51	5,4	0,50	5,4	0,50	5,2		
8	1-2-4-3 1-3-2-4 1-3-4-2 1-4-2-3	0,59 0,59 0,59 0,59	6,5 6,0 6,5 5,9	0,49 0,51 0,49 0,51	6,5 5,6 6,5 5,6	0,49 0,50 0,49 0,50	6,6 5,6 6,6 5,6	0,47 0,47 0,47 0,47	6,8 6,8 6,8 6,8	0,43 0,43 0,43 0,43	9,2 9,2 9,2 9,2 9,2		
10	1-4-3-2-5	0,59	6,1	0,49	6,7	0,47	7,4	0,43	9,4	0,45	8,1		
	1-5-2-3-4	0,59	6,2	0,49	6,7	0,47	7,4	0,43	9,4	0,45	8,1		
12	1-3-5-2-4-6	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6		
	1-5-3-4-2-6	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6		
	1-6-2-4-3-5	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6		
	1-6-4-2-5-3	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6		
14	1-6-3-4-5-2-7 1-7-2-5-4-3-6	0,54 0,54	9,0 9,0	0,43 0,42	10,3 10,6	0,41 0,40	10,7 10,7	0,41 0,41	10,1 10,4	0,41 0,42	10,3		
16	1-6-4-7-2-5-3-8	0,56	7,9	0,42	11,2	0,41	11,2	0,42	10,2	0,39	11,4		
	1-8-3-5-2-7-4-6	0,56	7,9	0,42	11,2	0,41	11,2	0,42	10,2	0,39	11,4		
18	1-6-8-2-5-7-3-4-9	0,51	11,4	0,41	12,0	0,41	11,6	0,41	10,8	0,40	11,9		
	1-9-4-3-7-5-2-8-6	0,51	11,4	0,40	12,4	0,40	11,8	0,40	11,5	0,40	11,9		
20	1-8-5-7-2-10-3-6-4-9	0,50	12,6	0,41	12,5	0,40	12,4	0,40	12,1	0,40	12,3		
	1-9-4-6-3-10-2-7-5-8	0,50	12,6	0,41	12,7	0,40	12,4	0,39	12,4	0,40	12,3		

CRANK SHAFT COEFFICIENTS A

No.	FIRING ORDER PER BANK			a Amo					MIN	NIMUM	FIRING	INTE	RVA
OF CYLS.	FROM FREE END OF ENGINE (Equal Intervals)	40°		45°		50°		60°		80°		90°	
	(Equal Intervals)	A	C	A	C	A	C	A	C	A	С	A	1
4		0,67	3,4	0,63	3,5	0,61	3,5	0,59	3,5	0,56	3,7	0,54	3
6	ALL	0,65	4,7	0,60	4,8	0,58	4,8	0,56	5,0	0,54	4,6	0,54	4
8	ALL	0,67	3,8	0,63	3,9	0,61	3,8	0,58	3,8	0,55	3,9	0,54	4
10	1-2-4-5-3	0,60	6,7	0,57	6,5	0,56	6,2	0,54	5,7	0,53	4,9	0,52	
10	1-3-5-4-2	0,60	6,8	0,57	6,4	0,55	6,1	0,54	5,6	0,53	4,9	0,52	
	1-2-4-6-3-5	0,63	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,51	5,8	0,50	
	1-2-4-6-5-3	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,7	0,51	5,9	0,52	
10	1-2-5-6-4-3	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,8	0,50	6,1	0,50	
12	1-3-4-6-5-2 1-3-5-6-4-2	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,7	0,51	5,7	0,52	
	1-3-3-6-4-2	0,63 0,64	5,4 5,9	0,59 0,58	5,5 5,9	0,57	5,6 5,9	0,54	5,9 5,9	0,51	5,9 5,8	0,50	
	1-5-3-6-2-4	0,64	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,53	5,4	0,50	
	1-5-3-6-4-2	0,63	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,51	5,7	0,52	
11	1-2-4-6-7-5-3	0,61	6,6	0,57	6,5	0,56	6,2	0,52	7,0	0,47	8,3	0,44	
14	1-3-5-7-6-4-2	0,60	6,6	0,57	6,6	0,56	6,3	0,52	6,5	0,47	8,5	0,45	
	1-2-4-6-8-7-5-3	0,59	7,6	0,55	7,6	0,54	7,5	0,50	7,6	0,45	9,0	0,43	
	1-3-2-4-8-6-7-5	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	
	1-3-5-2-8-6-4-7	0,59	7,2	0,56	7,0	0,55	6,8	0,52	7,1	0,45	9,0	0,43	
	1-3-5-7-8-6-4-2	0,59	7,6	- 0,55	7,6	0,54	7,5	0,50	8,1	0,45	9,0	0,43	
	1-3-7-5-8-6-2-4 1-4-2-6-8-5-7-3	0,60	6,9 6,9	0,56	6,8	0,55	6,8	0,51 0,52	7,2	0,45	9,0	0,43	
	1-4-6-2-8-5-3-7	0,60	7,6	0,56	6,8 7,4	0,55 0,54	6,8 7,2	0,52	7,1 7,1	0,45	9,0	0,43	
	1 1 7 0 0 7 0 0	0,61	6,7	0,59	7,4	0,54	7,0	0,52	6,5	0,45	9,0	0,43	
16	1-4-7-3-8-5-2-6	0,59	7,6	0,59	7,4	0,54	7,0	0,53	7,1	0,45	9,0	0,43	
10	1-5-7-6-8-4-2-3	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	
	1-6-2-4-8-3-7-5	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	
	1-6-2-5-8-3-7-4	0,59	7,6	0,59	7,4	0,54	7,0	0,53	6,5	0,45	9,0	0,43	
	1-6-4-2-8-3-5-7	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	
	1-6-4-7-2-5-3-8	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	
	1-7-3-5-8-2-6-4	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	
	1-7-4-6-8-2-5-3	0,59	7,2	0,59	7,0	0,54	8,1	0,50	7,6	0,45	9,0	0,43	
	1-7-5-3-8-2-4-6	0,59	7,6	0,59	7,6	0,54	7,0	0,52	7,1	0,45	9,0	0,43	
	1-8-3-5-2-7-4-6	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	
	1-2-4-6-8-9-7-5-3 1-3-5-7-9-8-6-4-2	0,58	8,4	0,54	8,3	0,52	8,4	0,48	9,1	0,42	10,7	0,43	1
18	1-5-9-3-6-8-2-4-7	0,58	8,4	0,54	8,3	0,51	8,6	0,48	8,8	0,42	10,7	0,43	1
280	1-7-4-2-8-6-3-9-5	0,59 0,59	7,2 7,1	0,56 0,56	7,4 7,0	0,54 0,54	7,6 7,3	0,50	8,2 8,2	0,43	10,3 10,3	0,44	
	1-4-3-2-5-10-7-8-9-6	0,59	7,8	0,56	7,9	0,53	8,3	0,48	9,5	0,44	10,2	0,45	
90	1-6-3-7-2-10-5-8-4-9	0,59	7,9	0,56	7,9	0,53	8,2	0,48	9,5	0.44	10,2	0,45	١.
20	1-6-9-8-7-10-5-2-3-4	0,58	7,8	0,54	8,1	0,51	8,4	0,48	9,3	0,44	10,2	0,45	
	1-9-4-8-5-10-2-7-3-6	0,58	7,8	0,56	7,9	0,53	8,3	0,48	9,3	0,44	10,2	0,45	

AND C FOR 4SCSA VEE ENGINES

27	0°	28	0°	30	O°	31	0°	31	5°	32	0°	PER BANK FROM FREE END OF ENGINE (Equal Intervals)	No. OF CYLS
A	C	A	C	A	C	A	C	A	C	A	C	(Equal Intervals)	
),48	4,0	0,48	4,0	0,47	3,8	0,46	3,9	0,45	4,0	0,45	4,1		4
,48	5,8	0,45	5,4	0,43	5,7	0,41	5,6	0,42	5,7	0,42	5,5	ALL	6
,47	4,8	0,47	4,9	0,45	4,8	0,45	4,6	0,45	4,5	0,45	4,1	ALL	8
,39 ,39	8,4 8,4	0,37 0,37	9,4 9,4	0,37 0,37	9,1 9,0	0,37 0,36	8,3 8,2	0,38 0,38	7,5 7,8	0,38 0,38	7,5 7,4	1-2-4-5-3 1-3-5-4-2	10
0,44 0,46 0,45 0,45 0,45 0,43 0,44	6,0 5,9 5,7 5,9 5,7 6,3 6,1 6,1	0,43 0,45 0,45 0,44 0,45 0,43 0,43	6,1 5,7 5,7 5,9 5,7 6,1 6,1 6,1	0,41 0,43 0,43 0,43 0,43 0,41 0,41 0,41	6,6 5,9 5,9 5,9 5,9 6,6 6,6 6,6	0,41 0,41 0,41 0,41 0,41 0,41 0,41	6,7 6,1 6,1 6,1 6,1 6,7 6,7 6,7	0,40 0,41 0,41 0,41 0,41 0,40 0,40 0,40	6,7 6,1 6,1 6,1 6,1 6,7 6,7 6,7	0,40 0,41 0,41 0,41 0,41 0,40 0,40 0,40	6,5 6,0 6,0 6,0 6,0 6,5 6,5 6,5	1-2-4-6-3-5 1-2-4-6-5-3 1-2-5-6-4-3 1-3-4-6-5-2 1-3-5-6-4-2 1-4-2-6-3-5 1-5-3-6-2-4 1-5-3-6-4-2	12
,43 ,43	6,8 6,6	0,41 0,41	7,8 7,6	0,35 0,35	10,2 10,1	0,33 0,33	10,7 10,9	0,33 0,33	10,6 10,5	0,33 0,33	10,1 10,1	1-2-4-6-7-5-3 $1-3-5-7-6-4-2$	14
0,36 0,36 0,36 0,36 0,36 0,36 0,36 0,36	10,3 10,3 11,4 10,3 10,3 10,3 11,4 10,3 10,3 10,3 11,6 10,3 11,6 11,4 11,4 11,4	0,38 0,37 0,36 0,38 0,37 0,36 0,37 0,37 0,37 0,37 0,35 0,38 0,35 0,41 0,36 0,38	9,4 9,5 10,6 9,4 9,5 10,6 9,4 9,4 9,4 9,4 11,9 9,4 11,9 12,1 10,6 9,4	0,40 0,41 0,37 0,40 0,40 0,40 0,37 0,39 0,39 0,39 0,37 0,41 0,37 0,37 0,37	7,6 7,4 8,7 7,6 7,6 7,3 8,7 8,1 8,1 7,4 8,1 9,1 7,4 9,1 8,7 8,7 7,4	0,40 0,41 0,38 0,40 0,40 0,40 0,38 0,39 0,39 0,39 0,39 0,39 0,38 0,41 0,38 0,38 0,38	7,1 6,8 8,1 7,1 7,1 6,9 8,1 7,5 7,5 6,8 7,5 7,5 8,1 6,8 8,3 8,1 8,1 6,8	0,39 0,41 0,37 0,39 0,39 0,40 0,38 0,39 0,41 0,39 0,37 0,40 0,37 0,37	7,3 6,5 7,9 7,3 7,0 6,8 7,9 7,3 6,5 7,3 7,3 8,1 6,9 8,1 7,9 7,9 6,9	0,39 0,41 9,38 0,39 0,39 0,40 0,38 0,39 0,39 0,37 0,39 0,37 0,38 0,38 0,38	6,8 6,3 7,8 7,4 7,0 6,6 7,8 7,2 7,2 7,2 7,2 7,9 7,2 7,9 7,8 7,8 7,8 7,2	$\begin{array}{c} 1-2-4-6-8-7-5-3\\ 1-3-2-4-8-6-7-5\\ 1-3-5-2-8-6-4-7\\ 1-3-5-7-8-6-4-2\\ 1-3-7-5-8-6-2-4\\ 1-4-2-6-8-5-7-3\\ 1-4-6-2-8-5-3-7\\ 1-4-7-3-8-5-2-6\\ 1-5-7-3-8-4-2-6\\ 1-5-7-6-8-4-2-3\\ 1-6-2-4-8-3-7-5\\ 1-6-2-4-8-3-7-5\\ 1-6-4-2-8-3-5-7\\ 1-6-4-7-2-5-3-8\\ 1-7-3-5-8-2-6-4\\ 1-7-4-6-8-2-5-3\\ 1-7-5-3-8-2-4-6\\ 1-8-3-5-2-7-4-6\\ \end{array}$	16
0,42 0,42 0,39 0,39	7,8 7,6 8,8 8,8	0,42 0,42 0,41 0,41	7,7 7,5 8,1 8,1	0,38 0,38 0,39 0,39	9,1 9,1 8,6 8,6	0,35 0,35 0,36 0,36	10,2 10,2 9,9 9,9	0,33 0,33 0,34 0,34	10,9 10,9 10,5 10,5	0,32 0,32 0,33 0,33	11,2 11,2 10,7 10,7	1-2-4-6-8-9-7-5-3 1-3-5-7-9-8-6-4-2 1-5-9-3-6-8-2-4-7 1-7-4-2-8-6-3-9-5	18
,40 ,36 ,40 ,36	9,1 11,0 9,1 11,0	0,37 0,33 0,37 0,33	10,3 12,0 10,3 12,0	0,36 0,33 0,36 0,33	10,1 11,4 10,1 11,4	0,37 0,35 0,37 0,35	9,1 10,2 9,1 10,2	0,37 0,35 0,37 0,35	8,7 9,7 8,7 9,7	0,37 0,36 0,37 0,36	8,3 9,1 8,3 9,1	1-4-3-2-5-10-7-8-9-6 1-6-3-7-2-10-5-8-4-9 1-6-9-8-7-10-5-2-3-4 1-9-4-8-5-10-2-7-3-6	20

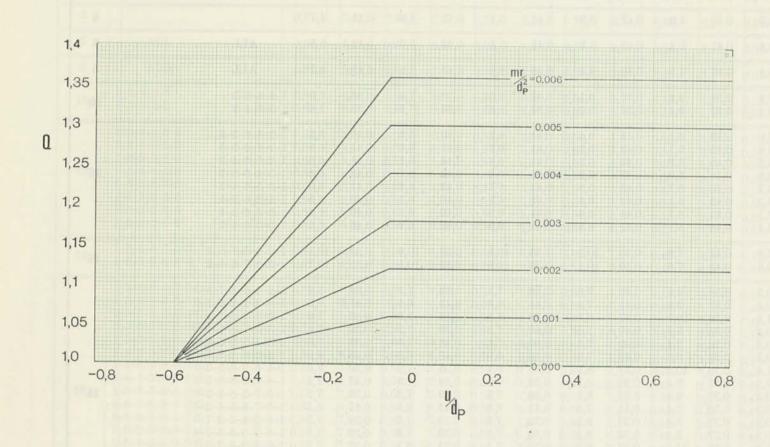


Fig. H 2.1

Fig. H 2.1

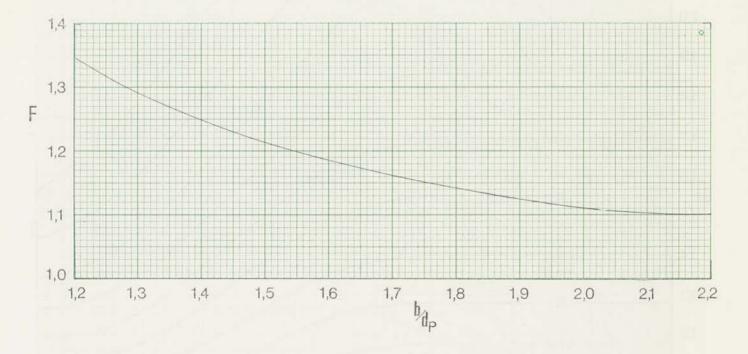


Fig. H 2.2



LLOYD'S REGISTER OF SHIPPING

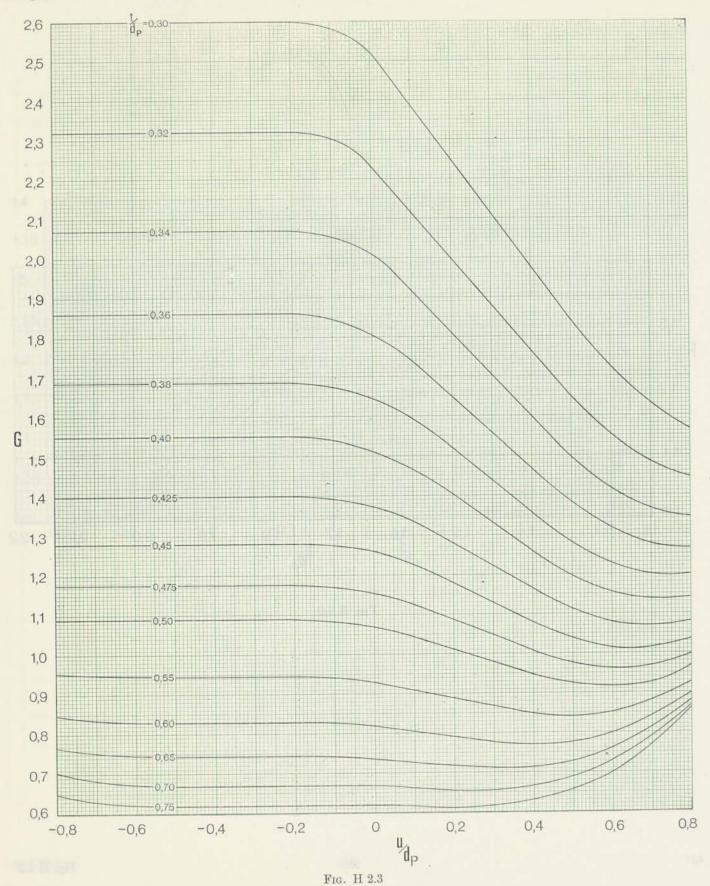


Fig. H 2.3

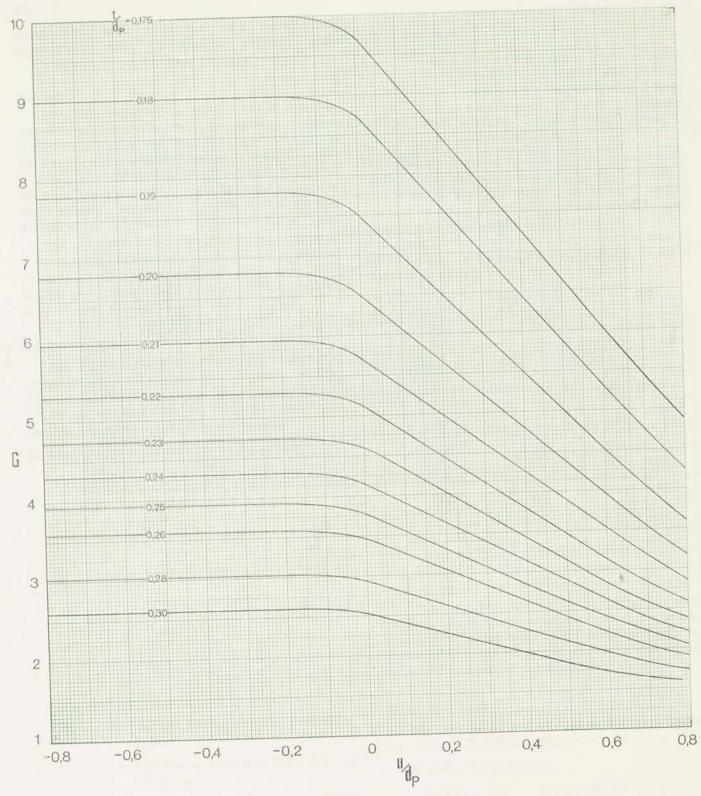


Fig. H 2.4

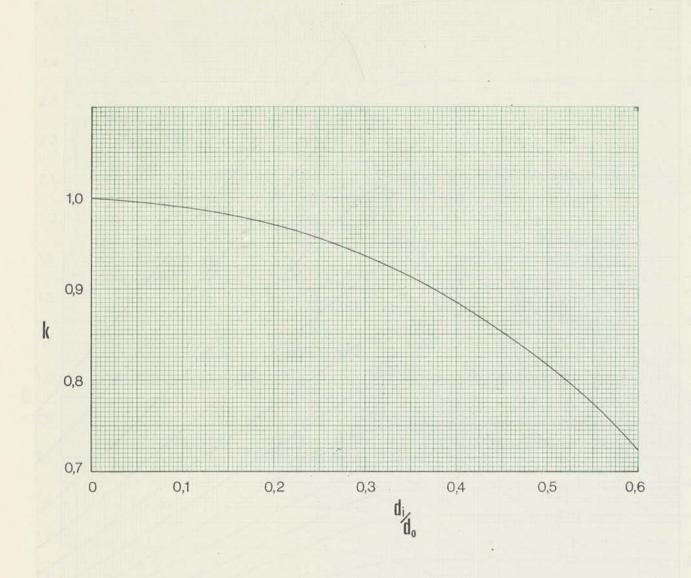


Fig. H 2.5

PART 2

GEAR AND LINE SHAFTING AND ASSOCIATED COMPONENTS FOR OIL ENGINE, TURBINE AND ELECTRIC PROPULSION INSTALLATIONS

Materials

221 The intermediate and other shafts of carbon or carbon-manganese steel are to have a specified minimum tensile strength of not less than 44 kg/mm² (28 ton/in²). Steel having a specified minimum tensile strength greater than 44 kg/mm² (28 ton/in²) but not exceeding 80 kg/mm² (50 ton/in²) may be used but screw shafts and tube shafts are, in general, to be restricted to a range of tensile strength between 44 and 52 kg/mm² (28 and 33 ton/in²).

The material is to comply with the requirements of Q 602 to Q 610 and where it is proposed to use a carbon or carbon-manganese steel having a specified minimum tensile strength greater than 60 kg/mm² (38 ton/in²) full details are to be submitted for consideration.

Intermediate Shaft

222 The diameter of the intermediate shaft d if of carbon or carbon-manganese steel, having a specified minimum tensile strength not less than 44 kg/mm² (28 ton/in²) but not exceeding 80 kg/mm² (50 ton/in²), is not to be less than determined by the following formulæ:—

Oil Engines, turbine and electric propelling motors

$$d = 25.4 \text{ C} \sqrt[3]{\frac{\text{H}}{\text{R}} \left(\frac{60}{\text{T} + 16}\right)} \text{ mm}$$
 (1)

$$\left(d=C\ \sqrt[3]{\frac{H}{R}\left(\frac{38}{T+10}\right)}\ in\ \right)$$

or, for oil engines where the necessary particulars are available

$$d = 89 \sqrt[3]{\frac{H}{R}} \left(\frac{X+A}{1+A}\right) \left(\frac{60}{T+16}\right) mm$$
 (2)

$$\left(d=3.5\ \sqrt[3]{\frac{H}{R}\left(\frac{X+A}{1+A}\right)\,\left(\frac{38}{T+10}\right)}\ \mathrm{in}\ \right)$$

where H and R are as defined in H 105,

T = specified minimum tensile strength, in kg/mm² (ton/in²),

C = coefficient obtained from Table H 2.5 for oil engines,

= 3.5 for turbines and electric propelling motors,

X = ratio of maximum to mean indicated torque at the after cylinder,

$$A = \frac{Je}{Jp}$$

Je = total mass moment of inertia of engine, including reciprocating and revolving parts and flywheel, also gearing if fitted,

Jp = mass moment of inertia of propeller including entrained water referred to crank shaft speed.

NOTE 1. Formula (1) is applicable only to single piston in-line engines with approximately equal firing intervals.

Note 2. Formula (2) is applicable to all engines without restriction of any kind and may allow, in some cases, a smaller shaft diameter than formula (1).

NOTE 3. Where a percentage figure for the mass of water entrained by the propeller is not available, it may be taken as 25 per cent.

TABLE H 2.5

4 STROKE SING	LE ACTING	2 STROKE SIN	GLE ACTING	
Number of Cylinders	С	Number of Cylinders	С	
1 to 4	4,30	1 or 2	4,50	
5	4,15	3	4,20	
6	4,05	4		
7	4,00	5	3,90	
8	3,90	6	3,80	
9	3,85	7	3,75	
10	3,70	8	3,65	
11 and over	3,55	9 & over	3,55	

NOTE. The Rule diameter of the intermediate shaft for oil engines, turbines and electric propelling motors may be reduced by 3,5 per cent for ships classed exclusively for smooth water service and by 1,75 per cent for ships classed exclusively for service on the Great Lakes.

Turbine Quill Shaft

223 The diameter of the quill shaft is not to be less than given by the following formula:—

Diameter of quill shaft =

$$89 \sqrt[3]{\frac{\text{H } 44}{\text{R T}}} \text{ mm} \qquad \left(3.5 \sqrt[3]{\frac{\text{H } 28}{\text{R T}}} \text{ in } \right)$$

where H and R are as defined in H 105.

T = specified minimum tensile strength of the material in kg/mm² (ton/in²), which is not to be less than 44 kg/mm² (28 ton/in²).

Final Gear Wheel Shaft

224 Where there is only one pinion geared into the final wheel, or where there are two pinions which are set to subtend an angle at the centre of the shaft of less than 120 degrees, the diameter of the shaft at the final wheel and the adjacent journals is not to be less than 1,16 times that required for the intermediate shaft.

Where there are two pinions geared into the final wheel opposite, or nearly opposite, to each other, the diameter of the shaft at the final wheel and the adjacent journals is not to be less than 1,1 times that required for the intermediate shaft.

In both the above cases, abaft the journals the shaft may be gradually tapered down to the diameter required for an intermediate shaft determined according to the appropriate formula in 222, where T is to be taken as the specified minimum tensile strength of the final wheel shaft material, in kg/mm² (ton/in²).

Thrust Shaft

225 The diameter at the collars of the thrust shaft transmitting torque is not to be less than 1,15 times that required for the intermediate shaft; outside the collars the diameter may be tapered down to that required for the intermediate shaft. In determining the diameter of the intermediate shaft in accordance with the appropriate formula in 222, T is to be taken as the specified minimum tensile strength of the thrust shaft material, in kg/mm² (ton/in²).

Tube Shaft

226 The diameter of the tube shaft (i.e., the shaft which passes through the stern tube, but does not carry the propeller) is not to be less than 1,14 times that required for the intermediate shaft, and any part of the shaft within or without the tube which may be exposed to sea water is not to be less than 1,17 times that required for the intermediate shaft. The diameter of the intermediate shaft is to be determined in accordance with the appropriate formula in 222 and is to be based on material having a specified minimum tensile strength of 44 kg/mm² (28 ton/in²).

Screw Shaft

227 The diameter of the screw shaft carrying the propeller is not to be less than given by the following formula:—

Diameter of screw shaft, in mm (in) = 1,14 d +
$$\frac{P}{C}$$

where d = diameter required for the intermediate shaft determined in accordance with the appropriate formula in 222, based on material having a specified minimum tensile strength of 44 kg/mm² (28 ton/in²), in mm (in). For limitations on the mechanical properties of screw shaft material, see Q 606,

P = diameter of the propeller, in mm (in),

C = 144 when the shaft is fitted with a continuous liner or is oil lubricated and provided with an approved type of oil sealing gland,

= 100 for other shafts.

Screw shafts which run in stern tubes may have the end forward of the stern gland tapered down to a diameter, at the coupling flange, of 1,14 times that required for the intermediate shaft. Abrupt changes in shaft section at the screw shaft to intermediate shaft couplings should be avoided.

Hollow Shafts

228 Where the thrust, intermediate, tube and screw shafts have central holes, the diameters of the shafts as determined by the foregoing formulæ need not be increased, provided the diameter of the central hole in a shaft does not exceed one-third of the shaft diameter.

Couplings

229 The thicknesses of the coupling flanges at the pitch circle of the bolt holes are not to be less than the diameters of the coupling bolts at the face of the couplings as required by 230, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. In the case of the thrust shaft/crank shaft coupling the dimensions of the coupling bolts and flange thickness are to be governed by the crank shaft requirements. The thickness of the screw shaft coupling flange is not to be less than 0,27 of the diameter required for the intermediate shaft, as determined by the appropriate formula in 222, based on material having a specified minimum tensile strength of 44 kg/mm² (28 ton/in²), in mm (in).

The fillet radius at the base of the coupling flange is not to be less than 0,08 of the diameter of the shaft at the coupling, but in the case of crank shafts, the fillet radius at the centre coupling flanges may be 0,05 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and should not be recessed in way of nuts and bolt heads.

All couplings which are attached to shafts are to be of approved dimensions.

Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

Where a coupling is shrunk on the parallel portion of a shaft or is mounted on a slight taper, for example by means of the oil pressure injection method, full particulars of the coupling including the interference fit should be submitted for special consideration.

See paragraph 108, Chapter R (E)—Guidance Notes on Torsional Vibration Characteristics of Main and Auxiliary Oil Engines.

Coupling Bolts

230 The diameter of the bolts at the joining faces of the couplings is not to be less than that given by the following formula:—

$$\begin{array}{l} {\rm Diameter~of} \\ {\rm coupling~bolts} = C~ \sqrt{\frac{d^3~Z}{n~r} \left(\frac{T_S+16}{T_D}\right) mm} \end{array}$$

$$\left(C\sqrt{\frac{d^3 Z}{n r}\left(\frac{T_s+10}{T_b}\right)} \text{ in }\right)$$

where n = number of bolts in the coupling,

 $r={
m radius}$ of pitch circle of bolts, in mm (in), $T_b={
m specified}$ minimum tensile strength of bolts, in kg/mm² (ton/in²).

For coupling bolts for thrust, intermediate, tube and screw shafts,

C = 0.51

d = diameter of intermediate shaft determined by the appropriate formula in 222, in mm (in).

7 = 1.0

T_s = specified minimum tensile strength of intermediate shaft, in kg/mm² (ton/in²).

For coupling bolts for crank shafts,

C = 0.43

d = minimum diameter of crank shaft as calculated from 203 for the proposed power rating (see H 105), in mm (in),

Z = appropriate value from 203,

T_S = specified minimum tensile strength of crank shaft, in kg/mm² (ton/in²).

Bronze or Gunmetal Liners on Shafts

231 The thickness of liners fitted on screw shafts or on tube shafts, in way of the bushes, is not to be less, when new, than that given by the following formula:—

$$t = \frac{\mathsf{D} + 230}{32} \, \mathrm{mm} \quad \left(t = \frac{\mathsf{D} + 9}{32} \, \mathrm{in} \, \right)$$

where t = thickness of the liner, in mm (in),

D = diameter of the screw or tube shaft under the liner, in mm (in).

The thickness of a continuous liner between the bushes is not to be less than 0,75 t.

232 Continuous liners should preferably be cast in one piece.

Where, however, liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of asbestos or other heat resisting material covered by a copper strip should be inserted between the shaft and liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyors' satisfaction.

Each continuous liner or length of liner is to be tested by hydraulic pressure to 2 kg/cm² (30 lb/in²) after rough machining.

Liners are to be carefully shrunk on, or forced on to the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

233 Effective means are to be provided for preventing water from having access to the shaft at the part between the after end of the liner and the propeller boss

Propeller Boss, Keys and Keyways

234 The propeller boss is to be a good fit on the screw shaft cone. The length of the forward fitting surface should be about one diameter. The forward edge of the bore of the propeller boss is to be rounded to about a 6 mm (0.25 in) radius.

235 Round ended or sled-runner ended type keys are to be used and the keyways in the propeller boss and cone of the screw shaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screw shaft at the top of the cone. The sharp edges at the top of the keyway are to be removed.

Two screwed pins should be provided for securing the key in the keyway and the forward pin should be placed at least one third of the length of the key from the end. The depth of the tapped holes for the screwed pins should not exceed the pin diameter, and the edges of the holes should be slightly bevelled.

The distance between the top of the cone and the forward end of the keyway is not to be less than 0,2 of the diameter of the screw shaft at the top of the cone.

The effective sectional area of the key in shear, in mm² (in²), is not to be less than $\frac{d^3}{2.5 d_1}$

where d = diameter required for the intermediate shaft determined in accordance with the appropriate formula in 222 based on material having a specified minimum tensile strength of 44 kg/mm² (28 ton/ in²), in mm (in),

> d₁ = diameter of shaft at mid-length of the key, in mm (in).

Stern Bush

236 The length of the bearing in the stern bush next to and supporting the propeller is to be as follows:—

(a) For water-lubricated bearings which are lined with lignum vitae, rubber composition or approved plastic material, the length is not to be less than four times the diameter required for the screw shaft under the liner.

Forced water lubrication is to be provided for all bearings lined with rubber or plastic and for those bearings lined with lignum vitae where the shaft diameter is 380 mm (15 in) or over. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastic and rubber bearings. The water grooves in the bearings should be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the plastic type.

The shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead or to the stern tube where the water supply enters the stern tube forward of the bulkhead.

- (b) For bearings which are white metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be such that the nominal bearing pressure resulting from the weight of propeller and shaft will not exceed 6,3 kg/cm² (90 lb/in²). In no case is the length of the bearing to be less than twice the diameter required for the screw shaft. The weight of the propeller and of screw shaft, and the type of oil sealing gland are to be stated when the plans are submitted for approval.
- (c) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil gland, the length of the bearing is, in general, not to be less than 4 times the diameter required for the screw shaft.
- (d) For bearings which are grease lubricated the length of the bearing is not to be less than 4 times the diameter required for the screw shaft.

Oil sealing glands fitted in ships classed for unrestricted service must be capable of accommodating the effects of differential expansion between hull and line of shafting in sea temperatures ranging from Arctic to Tropical. This requirement applies particularly to those glands which span the gap and maintain oil tightness between the stern tube and the propeller boss.

Where a tank supplying lubricating oil to the stern bush is fitted it is to be located above the load water line and is to be provided with a low level alarm device in the engine room.

Where stern bush bearings are oil lubricated, provision should be made for cooling the oil by maintaining water in the after peak tank above the level of the stern tube or by other approved means. Means for ascertaining the temperature of the oil in the stern tube should also be provided.

Note. Where there is compliance with the terms of (b) and (c) to the Surveyors' satisfaction a screw shaft will be assigned the notation O.G. in the supplement to the Register Book for periodical survey purposes (see C 1201).

Screw shafts which are grease lubricated are not eligible for the O.G. notation.

PART 3

TORSIONAL VIBRATIONS

General

241 In addition to the shafting complying with the requirements of Parts 1 and 2 of this Section, where applicable, approval is also dependent on the torsional vibration characteristics of the complete shafting system(s) being found satisfactory.

Calculations of the torsional vibration characteristics of the shafting system(s) are to be prepared and submitted for consideration. Unless the responsibility for preparing and submitting this information is specifically advised, it is the responsibility of the Shipbuilder as main contractor to ensure, in co-operation with the Enginebuilders, that this information is prepared and submitted.

Oil Engines

242 The relevant recommendations of Chapter R (E)—Guidance Notes on Torsional Vibration Characteristics of Main and Auxiliary Oil Engines, Section 1, should be adopted and torsional vibration calculations for the following shafting systems are to be submitted for consideration together with the associated plans, also the particulars as detailed in Table R (E) 2.1a of Section 2 of the above Guidance Notes.

- (1) Main oil engine propulsion systems, except in the case of ships classed for smooth water service when fitted with engines having powers less than 150 bhp.
- (2) Auxiliary oil engine machinery systems used for essential services, where the power developed by the auxiliary engines is 150 bhp or 100kW and over.

In the case of the systems referred to in (1) and (2), where critical speeds are found by calculation to show stresses approaching the limits given in Section 1 of Chapter R(E) within the range of working speeds, torsiograph records may require to be taken from the machinery for the purpose of verifying the calculations. Restricted speed ranges may be imposed on continuous running at speeds where the stresses, or the vibration torques as indicated by tooth separation and gear hammer, are considered to be excessive.

Where changes are subsequently made to a dynamic system which has been approved, e.g., by fitting a propeller of different design to the working propeller or a flexible coupling, revised torsional vibration calculations are to be submitted for consideration.

Attention is drawn to Section 2 of Chapter R (E) for the recommended method of calculation and form of submission.

Turbines and Electric Propelling Motors

243 With turbines or electric motors geared to the shafting and situated aft, calculations of the torsional vibration characteristics for the dynamic system formed by the turbine, motor, gearing, line shafting and propeller are to be submitted for consideration, together with plans of all shafting and propeller and details of power developed by individual turbines throughout the speed range.

Where changes are subsequently made to a dynamic system which has been approved, e.g., by fitting a propeller of different design to the working propeller, revised torsional vibration calculations are to be submitted for consideration.

Where serious critical speeds are found by calculation to occur within the range of working speeds torsiograph records may require to be taken from the machinery for the purpose of verifying the calculations.

Restricted speed ranges may be imposed on continuous running at speeds where the vibration torques, as indicated by tooth separation and gear hammer, are considered to be excessive.

Section 3

REDUCTION GEARING FOR PROPELLING AND AUXILIARY ENGINES

General

301 The following requirements, except where otherwise stated, are applicable to reduction gearing for main propelling purposes and for driving electric generators where the transmitted powers exceed 300 shp and 150shp for propulsion and auxiliary drives respectively. In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively. Bevel gears will be specially considered.

302 Particulars of the gearing are to be submitted with the plans for all propulsion gears and for auxiliary gears where the transmitted power exceeds 150 shp, as follows:—

Material specifications,
Shaft horse power and revolutions for each pinion,
Number of teeth in each gear,
Pitch circle diameters,
Helix angles,
Normal pitches of teeth,
Addenda,
Dedenda,
Face widths,

Pressure angles of teeth (normal or transverse), Minimum backlash, Centre distance.

Materials

303 The materials for pinions, pinion sleeves, wheel rims, flexible couplings and quill shafts are to be of approved composition and mechanical properties and are to comply with the requirements of Chapter Q. Manufacturer's certificates of test for materials may be accepted in cases where the transmitted power of gears is less than 150 shp.

In the selection of materials for pinions and wheels consideration is to be given to their compatibility in operation. In general, for gears of through-hardened steels, except in the case of low reduction ratios, provision is also to be made for a hardness differential between pinion teeth and wheel teeth for which purposes the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

DESIGN

Tooth Form

304 The tooth profile in the transverse section is to be of involute shape and the roots of the teeth are to be formed with smooth fillets of radii not less than 12 per cent of the normal pitch.

For propulsion gears the ends of the pinion and wheel teeth are to be cut back from the root at an angle of 45° to 60° to the pitch line in all cases where the ratio F/d exceeds 1,5.

where F = total axial length over pinion helices, less the gap, in mm (in),

d = pitch circle diameter of pinion, in mm (in).

The teeth of pinions and wheels of turbine gears are to be suitably tip-relieved in cases where any of the following conditions apply:—

- (i) Normal pitch of teeth exceeds the equivalent of 6,35 mm module (4 D.P. or 0.7854 in).
- (ii) Addendum of pinion teeth exceeds 65 per cent of total working depth of engagement.
- (iii) Ratio of total working depth of engagement to normal pitch of teeth exceeds 0,75.

All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing or finishing are to be removed.

Deflection of Pinions

305 In order to limit tooth opening arising from loaded deflections, the total axial length, in mm (in),

over the gear face, less gap where applicable, is not to exceed

cd

where d = pitch circle diameter of pinion, in mm (in),

C = factor to be determined as follows:-

A = helical angle in degrees.

(a) double-helical pinion meshing with one wheel

$$c = \frac{105 + A}{60}$$

(b) double-helical pinion meshing with two wheels diametrically opposed

$$C = \frac{80 + A}{40}$$

(c) single-helical pinion meshing with one or two wheels

$$c = \frac{75 + A}{60}$$

For spur gears the ratio, face width/diameter, is not to exceed 1,25.

Alternatively, manufacturers may present deflection calculations with details of any intended measures to improve load distribution.

Tooth Loading for Surface Stress

306 In order to limit the tooth surface stress, the tooth load for the proposed power rating (see H 105) is not to exceed that given by the following formula:—

$$W = K d \frac{G}{(G+1)}$$

where W = maximum permissible tangential tooth load, in kg/cm (lb/in), of overall face width, less gap where applicable.

K = loading factor derived as follows:-

(a) FOR TURBINE GEARING

$$K = \left(\frac{5850 + d N}{1600000}\right) SB$$

$$\left(\mathsf{K} = \left(\frac{230 + \mathsf{d} \; \mathsf{N}}{280}\right) \mathsf{S} \; \mathsf{B} \; \; \mathsf{British}\right)$$

(b) FOR OIL ENGINE GEARING

$$K = \left(\frac{2300 - d N}{170000}\right) S B$$

$$\left(K = \left(\frac{90 - d N}{30}\right) S B British\right)$$

where d = pitch circle diameter of pinion, in mm (in),

N = revolutions per minute of pinion, divided by 1000,

S = value according to Table H 3.1,

S₁ = specified minimum tensile strength of pinion material, in kg/mm² (ton/in²),

S₂ = specified minimum tensile strength of wheel material, in kg/mm² (ton/in²),

F = total axial length over the gear face, less gap, in mm (in),

H = F for single helical and spur gears, or F/2 for double helical gears,

pa = axial pitch of teeth, in mm (in),

G = gear ratio =

wheel speed number of teeth in wheel number of teeth in pinion

B = 1, if H
$$\geqslant$$
 1,15 p_a,
= 0,6, if H< 1,15 p_a,

For divided power transmission where a pinion meshes with two or more wheels or a wheel meshes with two or more pinions, the value of S applicable to that gear is to be reduced by 12 per cent.

The permissible loading may be increased by 10 per cent in single reduction gearing for main propelling purposes and in double reduction gearing where it is proposed to connect the primary and secondary gears of single helical gears or spurs, by means of a quill shaft, or approved equivalent, also for double helical gears where, in addition to a quill shaft, provision is made for either:—

- (i) a coupling providing axial articulation, or
- (ii) (a) both helices of the main wheel are finish hobbed in the same direction of rotation and at the same setting of the blank on the hobber table;
 or alternatively,
 - (b) the matching of the cumulative pitch errors on the two helices can be shown to be within acceptable limits.

Where single reduction gearing is used for auxiliary drives, the permissible loading may be increased by 15 per cent.

Where the teeth of gears made of through-hardened steels are finished by an approved post-hobbing process, or profile ground, or where it can be demonstrated in advance that the finish and profile of the teeth are equivalent, the permissible loading, resulting from the product of any allowance factors, may be increased by up to 25 per cent.

Tooth Loading for Bending Stress

307 In order to limit the bending stress at the root section of gear teeth for the proposed power rating (see H 105), the fillet radius should be blended smoothly into the involute profile, and the normal pitch of the teeth should not be less than that given by the following formula:—

$$p_n = \frac{J C W_1}{(110-A) U}$$

where p_n = normal pitch of the teeth, in mm (in),

W₁ = maximum proposed tangential tooth load, in kg/cm (lb/in), of overall face width, less gap where applicable,

F = total axial length over the gear face, less gap, in mm (in),

H = F for single helical and spur gears or F/2 for double helical gears,

pa = axial pitch of the teeth, in mm (in),

$$J = 1, \text{ if } H \geqslant p_a,$$

$$= 0.4 (3.5 - H/p_a), \text{ if } H < p_a,$$

$$C = \frac{1700 + N}{1200}, \text{ if } N \leqslant 1000,$$

$$= \frac{18000 + N}{8400}, \text{ if } N > 1000,$$

A = helical angle, in degrees.

For the pinion or wheel under consideration:-

N = revolutions per minute,

UTS = specified minimum tensile strength (of core material for surface-hardened steels), in kg/mm² (ton/in²),

$$\mathsf{U} = \frac{\mathsf{UTS} + 95}{450} \quad \left(\mathsf{U} = \frac{\mathsf{UTS} + 60}{2} \; \mathsf{British} \right)$$

if gear is through-hardened,

- = 0,56 (80 British) if gear is inductionhardened and ground, or nitrided after post-hobbing by an approved process,
- = 0,60 (85 British) if gear is nitrided and ground,
- = 0,67 (95 British) if gear is carburized, hardened and ground.

For an idler gear, C should be increased by 60 per cent.

For divided power transmission, where a pinion meshes with two or more wheels or a wheel meshes with two or more pinions, the value of U applicable to that gear is to be reduced by 12 per cent.

TABLE H 3.1

HEAT TREATMENT AND SURFACE CONDITIONS		S S S S S S S S S S S S S S S S S S S					
PINION	WHEEL	TURBINE	GEARING -	OIL ENGINE GEARING			
Through-Hardened	Through-Hardened	Metric value Lower value of $S_1 + 63$ or $\left(\frac{9+G}{10}\right)S_2+63$	British value Lower value of $S_1 + 40$ or $\left(\frac{9+G}{10}\right)S_2+40$	- Metric value Lower value of $S_1 - 8$ or $\left(\frac{9+G}{10}\right)S_2 - 8$	British value Lower value of S_1-5 or $\left(\frac{9+G}{10}\right)S_2-5$		
Carburized, Hardened and Ground	Through-Hardened	345	220				
Nitrided after post- hobbing by an approved process or Nitrided and Ground	Through-Hardened	(provided $S_2 \geqslant 63$)	(provided $S_2 \geqslant 40$)	$\left(\frac{9+G}{10}\right)S_2-8$	$\left(\frac{9+G}{10}\right)S_2-5$		
Carburized, Hardened and Ground	Induction-Hardened	470	300	300	100		
Nitrided after post- hobbing by an approved process or Nitrided and Ground	and Ground	470	300	300	190		
Nitrided after post- hobbing by an approved process or Nitrided and Ground	Nitrided after post- hobbing by an approved process or Nitrided and Ground	535	340	345	220		
Carburized, Hardened and Ground	Carburized, Hardened and Ground	570	360	380	240		

The permissible loading may be increased by 10 per cent in single reduction gearing for main propelling purposes and in double reduction gearing where it is proposed to connect the primary and secondary gears of single helical gears or spurs, by means of a quill shaft, or approved equivalent, also for double helical gears where, in addition to a quill shaft, provision is made for either:—

- (a) a coupling providing axial articulation, or
- (b) (i) both helices of the main wheel are finish-hobbed in the same direction of rotation and at the same setting of the blank on the hobber table; or alternatively,
 - (ii) the matching of the cumulative pitch errors on the two helices can be shown to be within acceptable limits.

Where single reduction gearing is used for auxiliary drives, the permissible loading may be increased by 15 per cent.

Where the teeth of gears made of through-hardened steels are finished by an approved post-hobbing process, or profile-ground, or where it can be demonstrated in advance that the finish and profile of the teeth are equivalent, U may be increased by up to 10 per cent for a specified minimum ultimate tensile strength not exceeding 88 kg/mm² (56 ton/in²). For higher specified tensile strengths, U will be limited to 0,45 (64 British).

The core tensile strength for surface-hardened steels must not be less than 79 kg/mm² (50 ton/in²).

Alternative proposals to the foregoing, together with calculations, may be submitted for special consideration.

CONSTRUCTION

Gear Wheels and Pinions

308 Where wheels are of cast construction any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

When bolts are used to secure side plates to rim and hub, the bolts are to be a tight fit in the holes and the nuts are to be suitably locked by means other than welding.

When welding is employed in the construction of wheels, the welding procedure is to be approved in the first instance by the Surveyors before work is commenced. For this purpose, test specimens representative of the welded joints used in the construction of the wheel are to be provided for examination and mechanical test. Sections are also to be taken from the test joints at positions selected by the Surveyors, and are to be macro-etched to verify that the welds are sound. Wheels are to be stress relieved after welding. All welds are to have a smooth surface and even contour and are to be proved by magnetic crack detection methods.

In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

Accuracy of Gear Cutting and Alignment

309 Turbine gearing is to be cut only on machines which are maintained at a high standard of accuracy. When large gears are designed with loading factors exceeding K=0.56 (80 British), any hobbing machines used in their production are to operate under conditions of temperature control.

The accuracy of gear-cutting and alignment of pinions and wheels is to be demonstrated in the workshop to the satisfaction of the Surveyors.

Balance of Gear Pinions and Wheels

310 For turbine gearing, all pinions, gear wheels and flexible coupling sleeves whose maximum designed speed of rotation exceeds 1000 revolutions per minute are to be dynamically balanced. Where the speed of rotation is 1000 revolutions per minute or less, these components are to be statically or, alternatively, dynamically balanced.

Parts of couplings, etc., which are to be fixed to the gear in service shall normally be attached before balancing.

For oil engine gearing, all pinions, gear wheels and flexible couplings are to be statically or dynamically balanced as for turbine gearing. Balancing may, however, be omitted provided these rotating components are of solid forged construction or have a solid forged centre with shrunkon rim, and in both cases are machined to give a concentric and uniform cross-section.

Gear Cases

311 Gear cases are to be of rigid design and if welding is employed in their construction they are to be stress relieved on completion (see also H 108).

Inspection openings are to be provided at the peripheries of gear cases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gear cases is such that sections of the structure cannot readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gear cases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

Trials

312 Prior to full power sea trials, the teeth of pinions and wheels are to be thinly coated with copper sulphate, an approved spirit lacquer, or other equivalent. After these trials, the marking revealed by inspection is to indicate freedom from hard bearing and not less than 70 per cent contact across the effective face width with satisfactory contact over the involute profile. Where the teeth of gears made of through-hardened steels are finished by an approved post-hobbing process, or profile ground, or where it can be demonstrated in advance that the finish and profile of the teeth are equivalent, and the increase in loading permitted by 306 and 307 is required, not less than 90 per cent contact across the effective face width should be indicated.

The sea trials are to be of sufficient duration to prove the gears. On conclusion, all gears are to be opened up sufficiently to permit the Surveyors to make an inspection of the teeth.

Cross-reference

313 For lubricating oil systems, see E 9.

Section 4

PROPELLERS

Materials

401 Where bronze or cast steel is used for propellers or propeller blades, the materials should comply with the relevant requirements of Chapter Q, or an approved specification.

Cast iron propellers are to be made of a high duty iron of at least 27 kg/mm² (17 ton/in²) tensile strength, or of a nodular or spheroidal graphite ductile type cast iron.

402 A plan, in triplicate, of the propeller is to be submitted for approval, together with the following particulars:—

Nomenclature and Units to be used in formulæ Maximum blade thickness of the expanded cylindrical section considered T in mm (in) Maximum shaft or brake horse power (see H 105) Revolutions per minute of the propeller at maximum power Propeller diameter D in metres (feet) Pitch at 25 per cent radius (for P_{0.25} in metres (feet) solid propellers only) Pitch at 35 per cent radius (for controllable pitch propellers P_{0.35} in metres (feet) only) Pitch at 60 per cent radius P_{0.6} in metres (feet) Por in metres (feet) Pitch at 70 per cent radius Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid L_{0,25} in mm (in) propellers only) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only) L_{0.35} in mm (in) Length of blade section of the expanded cylindrical section at 60 per cent radius Log in mm (in) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative) A in mm (in) N Number of blades B Developed area ratio Material: Chemical composition, also mechanical properties and density (if not included in Table

Minimum Blade Thickness

H 4.1)

403 The thickness of the propeller blades at the root (25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers) neglecting any increase due to fillets, and at 60 per cent radius is not to be less than:—

$$T = \frac{\text{KCA}}{\text{EFULN}} + 10 \sqrt{\frac{24\,000\text{MH}}{\text{EFRULN}}} \text{ mm}$$

$$\left(T = \frac{\text{KCA}}{\text{EFULN}} + 2.95 \sqrt{\frac{24\,000\text{MH}}{\text{EFRULN}}} \text{ in}\right)$$

where
$$L=L_{0,25}$$
, $L_{0,35}$ or $L_{0,6}$ as appropriate,
$$K=\frac{GBD^3R^2}{6600}$$

$$\left(K=\frac{GBD^3R^2}{150} \text{ British}\right)$$

G and U = material constants (see Table H 4.1).

For cases where the composition of the propeller material is not specified in Table H 4.1, or where propellers of the cast irons and carbon and low alloy steels shown in this Table are provided with an approved method of cathodic protection, special consideration will be given to the value of U.

 $\mathsf{E} = 1$ for aerofoil sections with trailing edge washback,

E = 1,25 for aerofoil sections without trailing edge washback.

For other blade section shapes, the value of E may be adjusted in the ratio

For solid propellers at 25 per cent radius:-

$$C = 1$$

$$F = \frac{P_{0,25}}{D} + 0.8$$

$$M = 1 + \frac{3.75D}{P_{0,7}} + 2.8 \frac{P_{0,25}}{D}$$

For controllable pitch propellers at 35 per cent radius:-

$$\begin{split} &C = 1,4 \\ &F = \frac{P_{0,35}}{D} + 1,6 \\ &M = 1,35 + \frac{5D}{P_{0,7}} + 2,6 \, \frac{P_{0,35}}{D} \end{split}$$

For all propellers at 60 per cent radius:-

$$C = 1,6$$

$$F = \frac{P_{0.6}}{D} + 4,5$$

$$M = 1,35 + \frac{5D}{P_{0.7}} + 1,35 \frac{P_{0.6}}{D}$$

For propellers of unusual design, or where the propeller is intended for more than one operating regime, such as towing or trawling, a detailed stress computation for the blades is to be submitted for consideration.

TABLE H 4.1

	Metrio			British		
Material	Specified Minimum Tensile Strength kg/mm ²	G Density kg/cm ³	U Allowable Stress kg/mm ²	Specified Minimum Tensile Strength ton/in ²	G Density lb/in ³	U Allowable Stress 1b/in ²
Cast Iron (Grey or Low Alloy)	27	7,2	1,75	17	0.26	2500
Spheroidal Graphite or Nodular Cast Iron	44	7,3	2,1	28	0.26	3000
Carbon and Low Alloy Steels	44	7,9	2,1	28	0.29	3000
13% Chromium Stainless Steels	55	7,7	4,2	35	0.28	6000
Chromium-Nickel Austenitic Stainless Steels	55	7,9	4,2	35	0.29	6000
5% Nickel 8% Aluminium Bronzes	65	7,7	5,7	41.3	0.28	8100
8% Aluminium 12% Manganese Bronzes	65	7,5	5,7	41.3	0.27	8100
Manganese Bronzes	45	8,3	4,0	28-6	0.30	5700

Section 5

STRENGTHENING FOR NAVIGATION IN ICE (GENERAL SERVICE)

General

501 Where the notation "Ice Class 1*, 1, 2 or 3" as specified in B 114 (a) is desired, the following requirements are to be complied with, so far as these are applicable.

(For northern Baltic service see H 5A.)

Power of Propelling Machinery

502 The power delivered to the propeller shafting (shp) is not to be less than C \perp B

where L = length of ship, between perpendiculars, in metres (feet),

B = breadth of ship, moulded, in metres (feet),

C = 2,1 (0·195 British) for Class 1*
1,79 (0·166 British) for Class 1
1,31 (0·122 British) for Class 2
0,98 (0·091 British) for Class 3.

Turbines

503 Where turbines are used for the propulsion of ships intended for Class 1*, 1 or 2 ice strengthening, the propeller shafting is to be driven by electrical or other approved means capable of protecting the turbines from shock.

Electric Motors

504 Where direct current electric motors are used for the propulsion of ships intended for Class 1*, 1 or 2 ice strengthening, provision is to be made for automatically limiting the transmitted torque to a safe value.

Materials

505 The propulsion shafting is to be of steel and the associated couplings are to be of steel or other approved material. For the material of screw shafts, see Q 601 to Q 610.

506 Propellers and propeller blades are to be of east carbon steel, alloy steel or bronze having tensile strength of not less than 44 kg/mm² (28 ton/in²). The material is to comply with the requirements of Q 5 or Q 9.

Main Engine Shafting, Gearing and Propellers

507 The diameters of the shafting as required by the rules for ocean-going service are to be increased by the percentages stated in Table H 5.1. No increase in the diameter of crank shafts of oil engines is required.

If gearing is fitted between the engine and propeller shafting, the gearing is to be designed and constructed to transmit torque in excess of that corresponding to the engine power by the percentages given in Table H 5.1.

The thicknesses of the blades at the root and at 60 per cent radius as required by H 403 are to be increased by the percentages stated in Table H 5.1.

TABLE H 5.1

Class	1*	1	2	3
Gearing, torque increase	50%	25%	15%	_
Thrust and intermediate shaft, increase in diameter	12%	8%	4%	
Screw shaft, increase in diameter	20%	15%	8%	5%
Propeller, increase in blade thickness	35%	25%	15%	8%

Minimum Propeller Blade Tip Thickness

508 The tip thickness t of the blade at 95 per cent radius is not to be less than that obtained by the following formula for Class 1*, 1, 2 and 3 ice strengthening:—

t = 0,14 (T + 57)
$$\sqrt[3]{\frac{44}{S}}$$
 mm
 $\left(t = 0.14 (T + 2.25) \sqrt[3]{\frac{28}{S}} \text{ in}\right)$

where T = blade root thickness required for appropriate Class, in mm (in),

S = Specified minimum tensile strength of material, in kg/mm² (ton/in²).

The edges of the blades are to be suitably thickened for the operating conditions but are not to be less than 50 per cent of the required tip thickness t, measured at 1,25 times tip thickness t from the edge. For controllable pitch propellers, this requirement need only be applied to the loading edges of the blades.

Ship-side Valves

509 The sea inlet and overboard discharge valves which are situated at or below the maximum load line, are to be provided with a low pressure steam or compressed air connection for clearing purposes, see E 267 and E 271.

Where steam is not available for clearing, it is recommended that arrangements be made for supplying water for machinery cooling purposes by circulating from ballast tank(s) of adequate capacity preferably situated in the double bottom. Such tank(s) are to be used only for storage of water ballast or fresh water.

510 Connections are to be fitted between the cooling water overboard discharge lines and sea inlets for main and auxiliary engine cooling water systems so that warm water may be used to assist in maintaining the suction pipes free from ice.

Where the cooling water inlet valves are fitted to a common water box, the connections from the cooling water discharge lines may be led to the water box in a position as near as possible to the inlet valves.

511 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from the main cooling water inlet pipe.

Cross-references

512 For hull requirements, see D 24, and for general requirements for ship-side valves, see E 267 to E 271.

Section 5A

STRENGTHENING FOR NAVIGATION IN ICE (NORTHERN BALTIC SERVICE)

General

520 Where the notation "Ice Class IA Super, IA, IB or IC" as specified in B 114 (b), is desired, the following requirements (given in metric units only) are to be complied with, so far as these are applicable.

Definitions

521 The displacement, V, is that related to the summer load line assigned, in tonnes. (Specific gravity of water = 1,0.)

Power of Propelling Machinery

522 For the different ice classes, the shaft horse power, H, is not to be less than that determined by the following formulae, and is not to be less than 1000 for any

ice class and not less than 3500 for Ice Class IA Super. The minimum required shp and the lower limits may be reduced by 10 per cent, if the ship is fitted with a controllable pitch propeller and reversible main machinery. For a ship fitted with steam turbines the astern power is to be at least 70 per cent of the ahead shp.

Ice Class IA Super

H = 0.40 V + 1500; but need not exceed 25 500.

Ice Class IA

H = 0.35 V + 1000; but need not exceed 22 000.

Ice Class IB

H = 0.30 V + 500; but need not exceed 18 500.

Ice Class IC

H = 0,25 V; but need not exceed 15 000. where V is as defined in 521.

Determination of Ice Torque

523 Dimensions of propellers, shafting and gearing are determined by formulae taking into account the impact when a propeller blade hits ice. The ensuing load is hereinafter defined by the ice torque M.

 $M = m D^2$ tonne metres.

where D = diameter of propeller, in metres, and

m = 2,15 for Ice Class IA Super

= 1,60 for Ice Class IA

= 1,33 for Ice Class IB

= 1,22 for Ice Class IC

If the propeller is not fully submerged when the ship is in ballast condition, the ice torque for Ice Class IA is to be used for Ice Classes IB and IC.

Propellers

524 For steel propellers the elongation of the material used is not to be less than 19 per cent for a test piece length = 5 d, and the value for the Charpy V-notch test is not to be less than 2,1 kg m at -10° C. See also Q 5.

525 Width L and thickness T of propeller blade sections are to be determined so that:—

(a) at the radius 0,25 D/2, for solid propellers
2 700 000 / H

$$\mathsf{LT^2} \geqslant \frac{2\,700\,000}{\mathsf{S}\,(0.65+0.7\;\mathsf{P/D})} \left(20\;\frac{\mathsf{H}}{\mathsf{NR}}\,+\,22\;\mathsf{M}\right)$$

(b) at radius 0,35 D/2 for controllable pitch propellers

$$\mathsf{LT^2} \geqslant \frac{2\,150\,000}{\mathsf{S}\;(0.65\,+\,0.7\;\mathsf{P/D})} \left(20\;\frac{\mathsf{H}}{\mathsf{NR}}\,+\,23\;\mathsf{M}\right)$$

(c) at the radius 0,6 D/2

$$LT^2 \geqslant \frac{950\,000}{S\,(0.65\,+\,0.7\,P/D)} \left(20\,\frac{H}{NR} + 28\,M\right)$$

where L = length, in mm, of the expanded cylindrical section of the blade, at the radius in question,

T = the corresponding maximum blade thickness, in mm,

 $\begin{aligned} \mathsf{P} &= \text{propeller pitch, in metres, at the radius in} \\ &\quad \text{question.} \end{aligned} \quad \text{(For controllable pitch propellers $\mathsf{P}_{\text{nominal}}$ is to be used.),}$

D = diameter of propeller, in metres,

H = shaft horse power as defined in H 105,

R = propeller rpm,

M = ice torque as defined in 523,

N = number of blades,

S = specified minimum tensile strength, in kg/mm², of the material.

526 The blade tip thickness, t at the radius D/2 is to be determined by the following formulae:—

Ice Class IA Super

$$t = (20 + 2 D) \sqrt{\frac{50}{S}} mm$$

Ice Classes IA, IB and IC

$$t = (15 + 2 \; D) \; \sqrt{\frac{50}{S}} \; \; \mathrm{mm}$$

where D and S are as defined in 525.

527 The thickness of other sections is to conform to a smooth curve connecting the section thicknesses as determined by 525 and 526.

528 Where the blade thickness derived by 525 is less than the blade thickness derived by H 403, the latter is to apply.

529 The thickness of blade edges is not to be less than 50 per cent of the derived tip thickness t, measured at 1,25 t from the edge. For controllable pitch propellers this applies only to the leading edge.

530 The strength of mechanisms in the boss of a controllable pitch propeller is to be 1,5 times that of the blade when a load is applied at the radius 0,9 D/2 in the weakest direction of the blade.

Screw Shafts

531 The diameter, d_s, at the aft bearing of the screw shaft fitted in conjunction with a solid propeller is not to be less than:—

$$d_{\text{S}} = 1.08 \ \sqrt[3]{\frac{\text{SLT}^2}{f_{\text{y}}}} \ \mathrm{mm}$$

where S = specified minimum tensile strength of the blade material, in kg/mm²,

L and T = proposed width and thickness respectively of the propeller blade section at 0,25 D/2, in mm,

fy = specified minimum yield stress of the material of the screw shaft, in kg/mm².

The diameter, d_s, at the aft bearing of the screw shaft fitted in conjunction with a controllable pitch propeller is not to be less than:—

$$d_{\text{S}} = 1.15 \ \sqrt[3]{\frac{\text{SLT}^2}{f_{\text{y}}}} \ \text{mm}$$

where L and T = proposed width and thickness respectively of the propeller blade section at 0,35 D/2, in mm.

532 Where the screw shaft diameter derived by 531 is less than the diameter derived by H 227, the latter is to apply.

The shaft may be tapered at the forward end in accordance with H 227.

Intermediate and Thrust Shafts

533 The diameters of intermediate shafts and thrust shafts in external bearings are to comply with H 222 and H 225, respectively, except for Class IA Super ice strengthening where these diameters are to be increased by 10 per cent.

Reduction Gearing

534 Where gearing is fitted between the engine and the propeller shafting, the gearing is to be in accordance with H 3 and is to be designed to transmit a torque, Y_i, determined by the following formula:—

$$Y_i = Y + \frac{M I_h G^2}{I_I + I_h G^2}$$

where $Y = 0.716 \frac{H}{R}$ (H and R are as defined in H 105),

M = ice torque as defined in 523,

$$G = \text{gear ratio} = \frac{\text{pinion speed}}{\text{wheel speed}},$$

 $I_h = mass$ moment of inertia of machinery components rotating at higher speed,

I_I = mass moment of inertia of machinery components rotating at lower speed, including propeller with an addition of 30 per cent for entrained water.

(Ih and II are to be expressed in the same units.)

Starting Arrangements

535 In addition to complying with the requirements of H 608 to H 611 where applicable, the capacity of air receivers and/or compressors, or other starting equipment, is to be sufficient for frequent starts within periods lasting several hours.

Sea Inlet Chests

536 At least one large cooling water inlet chest is to be connected to the cooling water discharge pipe line by a branch pipe line having the main pipe line diameter, in order to stay free from ice and slush ice. An inlet chest situated well aft in the garboard strake is recommended.

537 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from the cooling water inlet chest referred to in 536.

Cross-references

538 For hull requirements, see D 24A.

For ship-side valves, see E 267 to E 271.

For materials of propulsion shafting and associated couplings, see H 505.

Section 6

GENERAL REQUIREMENTS FOR OIL ENGINES AND STARTING AIR COMPRESSORS

Ventilation

601 Special attention is to be given to the ventilation of the engine room.

Relief Valves

602 Cylinder relief valves are to be fitted to engines having cylinders over 230 mm ($9 \cdot 0$ in) bore. The valves are to be loaded to not more than 40 per cent above the designed maximum pressure and are to discharge where no damage can occur.

In the case of auxiliary engines, consideration will be given to the replacement of the relief valve by an efficient warning device of overpressure in the cylinder.

603 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

Exhaust Systems

604 The exhaust pipes and silencer are to be water cooled or efficiently lagged to prevent damage by heat; if the exhaust is led overboard near the waterline, means are to be provided to prevent water from being syphoned back to the engine.

Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard.

Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economiser an isolating device is to be provided in each exhaust pipe.

For alternatively fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

In two-stroke main engines fitted with exhaust gas turbo-blowers which operate on the impulse systems, provision is to be made to prevent broken piston rings entering the turbine casing and causing damage to blades and nozzle rings.

Governors and Overspeed Protective Devices

605 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

606 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed setting, are to control the speed within the following limits:—

10 per cent momentary variation and 5 per cent permanent variation in speed when full load is suddenly taken off or, when after having run on no-load for at least 15 minutes, not less than 70 per cent full load is suddenly applied, followed by the remaining 30 per cent, except in the case of emergency generators which are to be capable of accepting full load under the same test conditions. For a.c. installations, the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of ± 0.5 per cent.

607 Each main engine developing 300 BHP or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 300 BHP and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 605 or 606 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

Starting Arrangements

engines is to be provided so that the necessary initial charge of starting air or initial electric power can be developed on board ship without external aid. If for this purpose an emergency air compressor or electric generator is required, these units are to be power driven by hand starting oil engine or steam engine, except in the case of small installations where a hand operated compressor of approved capacity may be accepted. Alternatively, other devices of approved type may be accepted as a means of providing the initial start.

609 Two or more starting and manœuvring air compressors are to be fitted of sufficient total capacity for the requirements of the main engines.

The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C (200°F) in service. A small fusible plug or an alarm device operating at 121°C (250°F) is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube. It is recommended that compressors be cooled by fresh water.

610 Where the main engines are arranged for air starting the total air receiver capacity is to be sufficient to provide, without replenishment, not less than twelve consecutive starts of each main engine if of the reversible type and not less than six consecutive starts if of the non-reversible type. In passenger ships, at least two air receivers are to be provided. For scantlings and fittings of air receivers, see J 2, J 3 and J 6.

611 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 610. In other respects batteries are to comply with the requirements of M 13.

Starting Air Pipe Systems and Safety Fittings

612 In designing the compressed air installation care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or alternatively an air duct from outside the machinery space is to be led to the compressors.

The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit of slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipe lines, drain valves are to be fitted to suitably located drain pots or separators.

The starting air piping system is to be protected against the effects of explosions by the following arrangements. An isolating non-return valve or equivalent is to be provided at the starting air supply connection to each engine. In direct reversing engines bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in small ships where the power of the main engine is less than 1500 bhp provided all the pipes in the system are made at least twice as thick as required by E 506 or E 512 and E 513.

Alternative safety arrangements may be submitted for consideration.

Crank Case Safety Fittings

613 Crank cases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices, of an approved type, to relieve the crank cases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed to open at a pressure not greater than 0,2 kg/cm² (2·8 lb/in²).

The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

The discharge from the valves is to be shielded by flame guard or flame trap to minimize the possibility of danger and damage arising from the emission of flame.

614 In engines having cylinders not exceeding 200 mm (8 in) bore and having a crank case gross volume not exceeding 0,6 m³ (20 ft³), relief valves may be omitted.

In engines having cylinders exceeding 200 mm (8 in) but not exceeding 250 mm (10 in) bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crank case. Where the engine has more than 8 crank throws an additional valve is to be fitted near the centre of the engine.

In engines having cylinders exceeding 250 mm (10 in) but not exceeding 300 mm (12 in) bore at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9 etc. crank throws, the number of relief valves is not to be less than 2, 3, 4, 5 etc. respectively.

In engines having cylinders exceeding 300 mm (12 in) bore at least one valve is to be fitted in way of each main crank throw.

Additional relief valves are to be fitted for separate spaces on the crank case, such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m³ (20 ft³).

615 The combined free area of the crank case relief valves fitted on an engine is not to be less than $115~\rm cm^2/m^3$ $(0.5~\rm in^2/ft^3)$ based on the volume of the crank case.

The free area of each relief valve is not to be less than 45 cm² (7 in²).

Notes. (1) The free area of the releif valve is the minimum flow area at any section through the valve when the valve is fully open.

- (2) In determining the volume of the crank case for the purpose of calculating the combined free area of the crank case relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crank case.
- 616 Alarms giving warning of the overheating of engine running parts, indicators of excessive wear of thrusts and

other parts, and detectors of smoke in the crank case are recommended as means for reducing the explosion hazard. These devices should be arranged to give an indication of failure of the equipment or of the instrument being switched off when the engine is running.

- 617 Crank cases and their doors are to be of robust construction and the doors are to be securely fastened so that they will not be readily displaced by an explosion.
- 618 Where crank case vent pipes are fitted, they are to be made as small as practicable to minimize the inrush of air after an explosion. Vents from crank cases of main engines are to be led to a safe position on deck or other approved position.

If provision is made for the extraction of gases from within the crank case, e.g., for smoke detection purposes, the vacuum within the crank case is not to exceed 25 mm (1 in) of water.

Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crank cases.

- 619 A warning notice is to be fitted in a prominent position, preferably on a crank case door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crank case, the crank case doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crank case.
- 620 Crank cases of starting air compressors are to be fitted with explosion relief devices as required for auxiliary engines in cases where the crank case volume is 0,60 m³ (20 ft³) and over.

Crank Case Lighting

621 Where interior lighting is provided it is to be flame proof in relation to the interior and details are to be submitted for approval. No wiring is to be fitted inside the crank case.

Hydraulic Tests

622 In general, items are to be tested by hydraulic pressure as indicated in Table H 6.1. Where design features are such that modifications to the test requirements shown in Table H 6.1 are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

Astern Power

623 Ships are to have sufficient power for going astern to secure proper control of the ship in all normal circumstances.

Trials

624 The sea trials are to be of sufficient duration to prove the machinery under power and normal manœuvring conditions.

It is to be demonstrated that the capacity of starting air receivers is adequate to provide the required number of starts of the main engines.

In the case of passenger ships, the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manœuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trials.

All trials are to be to the Surveyor's satisfaction.

Cross-references

625 The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapter E.

626 Oil fuel pipe systems, tanks and their fittings are to comply with the requirements of D 19 and Chapter E.

627 For lists of spare gear to be carried, see Chapter K.

TABLE H 6.1

ITEM			TEST PRESSURE	
Fuel injection system	Pump bod pressure s Valve Pipe	ly, ide	The lesser of 1,5 P or P+300 kg/cm ² (P+4250 lb/in ²)	
Cylinder cover, cooling space Cylinder liner, internally and over the whole length of cooling space Piston crown, cooling space (after assembly with piston rod)			7 kg/cm ² (100 lb/in ²)	
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo-blower, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)			The greater of 4 kg/cm ² (55 lb/in ²) or 1,5 P	
Air compressor, including cylinders, covers, intercoolers and aftercoolers		air side	1,5 P	
		water side	The greater of 4 kg/cm ² (55 lb/in ²) or 1,5 P	
Scavenge pump cylinder			4 kg/cm ² (55 lb/in	

P is the maximum working pressure in the item concerned

Section 7

WELDED STRUCTURES FOR OIL ENGINES

General

701 The requirements of this section are applicable to engines for main propelling purposes.

Plans

702 Before construction is commenced plans of bedplates, crank cases, frames and entablatures, including details of the welded joints, materials, electrodes and heat treatment are to be submitted for consideration.

An outline of the welding procedure and fabrication method and sequence is also to be submitted for information.

Note: It will not be necessary for plans and particulars to be submitted for each ship provided the basis plans for the engine size and type have previously been approved as meeting the requirements of these Rules. Any alterations to basis design, materials and manufacturing procedure are to be re-submitted for consideration.

Materials

703 Plates, sections, forgings and castings are to be of welding quality to an approved specification with a carbon content generally not exceeding 0,23 per cent, and are to be tested in accordance with the requirements of Chapter Q. Steels with higher carbon contents may be approved subject to special tests to prove weldability.

Construction

704 Plates and weld preparations are to be accurately machined or flame-cut to shape. Flame-cut surfaces are to be cleaned by machining or grinding; if the flame-cut surfaces are smooth, wire brushing may be accepted.

Before welding is commenced the component parts of bedplates and framework are to be accurately fitted and aligned. The welding is to be done in positions free from draughts and is to be downhand wherever practicable. Electrodes are to be of an approved type. Pre-heating is to be adopted when welding heavy plates or sections. The finished welds are to have an even surface and be free from undercutting. Welds attaching bearing housings to the transverse girders are to have a smooth contour and if necessary are to be made smooth by grinding.

Welded Joints

705 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding and inspection can be effected without difficulty. Abrupt changes in plate section are to be avoided and where plates of substan-

tially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

Heat Treatment

706 Bedplates are to be stress relieved except for engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For the latter types only the transverse girder assemblies need be stress relieved.

Stress relieving is to be done by heating the welded structure uniformly and slowly to a temperature between 580°C to 650°C (1080°F to 1200°F), holding that temperature for not less than one hour per 25 mm (1 in) of maximum plate thickness and thereafter allowing the structure to cool slowly in the furnace.

Inspection

707 Welded engine structures are to be examined during fabrication, special attention being given to the fit of component parts of major joints prior to welding. On completion of welding and stress relieving, all welds are to be examined. Welds in transverse girder assemblies are to be crack detected by an approved method to the satisfaction of the Surveyors. Other joints are to be similarly tested if required by the Surveyors.

The whole of the welding work is to be to the satisfaction of the Surveyors.

DESIGN RECOMMENDATIONS

It is recommended that bedplates and major components of engine structures should be made with a minimum number of welded joints.

Double welded butt type joints should be adopted wherever possible in view of their superior fatigue strength.

Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

Steel castings should be used for parts which would otherwise require complicated weldments.

Care should be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

Section 8

GENERAL REQUIREMENTS FOR STEAM TURBINES

Scope

801 The following requirements are applicable to steam turbines for main propulsion and for essential auxiliary services where powers exceed 150 shp.

Plans

802 The following plans are to be submitted for consideration, together with particulars of materials and of maximum shaft horse powers and revolutions per minute (see H 105). The pressures and temperatures applicable at maximum shaft horse power and under the emergency conditions of 836 are to be stated or indicated on the plans.

- 1. General arrangement.
- 2. Sectional assembly.
- 3. Rotors and couplings.
- 4. Cylinders.

For the emergency conditions of 837, full particulars are to be submitted of the means proposed for emergency propulsion.

For main turbines plans 1, 2 and 3 are required in all cases and 4 when the cylinders are of welded construction. In general for auxiliary turbines no plans need be submitted.

Where rotors and cylinders are of welded construction plans showing details of the welded joints are also to be submitted for consideration.

Materials

803 Plates, forgings, castings and pipes used in the construction of turbine cylinders, rotors, discs, couplings and other important components are to be of approved composition and be tested in accordance with the relevant requirements of Chapter Q, or of an approved Specification.

804 In the selection of materials for high temperature applications in advanced turbines consideration is to be given to their creep strength, corrosion resistance and scaling properties at working temperatures to ensure satisfactory performance and long life under service conditions.

805 Turbine rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings the specified range of tensile strength is not to exceed 10 kg/mm² (6·3 ton/in²) within the general limits of 45 and 70 kg/mm² (28·6 and 44·5 ton/in²). For alloy steel rotor forgings the specified range is not to exceed 15 kg/mm²

(9.5 ton/in²) within the general limits of 45 and 95 kg/mm² (28.6 and 60.3 ton/in²). For discs and other alloy steel forgings the specified range is not to exceed 15 kg/mm² (9.5 ton/in²) within the general limits of 45 and 115 kg/mm² (28.6 and 73 ton/in²).

When it is proposed to use a steel of higher tensile strength full details are to be submitted for approval. (See Q 631 to Q 640).

806 Turbine cylinder castings are to be of approved material suitable for the working metal temperature. Ordinary cast iron is not to be used for temperatures exceeding 260°C (500°F). The castings are to be stress relief heat treated after rough machining, except that this requirement may be waived for small castings at the Surveyors' discretion. The stress relieving temperature is not to exceed the tempering temperature. (See Q 504 and Q 507 for Steel Castings.)

Stability Testing of Turbine Rotors

807 All solid forged H.P. turbine rotors intended for main propulsion service where the inlet steam temperature exceeds 400°C (750°F) are to be subjected to at least one thermal stability test. This requirement is also applicable to rotors fabricated as in 820. The test may be carried out at the Forge or Turbine Builders' Works (a) after heat treatment and rough machining of the forging, or (b) after final machining, or (c) after final machining and blading of the rotor. The stabilizing test temperature is not to be less than 28 degC (50 degF) above the maximum steam temperature to which the rotor will be exposed and not more than the tempering temperature of the rotor material. For details of a recommended test procedure and limits of acceptance, see Q 637(e). Other test procedures may be adopted if approved.

Where main turbine rotors are subjected to thermal stability tests at both Forge and Turbine Builders' Works the foregoing requirements are applicable to both tests. It is not required that auxiliary turbine rotors be tested for thermal stability, but if such tests are carried out, the requirements for main turbine rotors will be generally applicable.

Design and Construction

808 In the design and arrangement of turbine machinery adequate provision is to be made for the relative thermal expansion of the various turbine parts, and special attention is to be given to minimizing easing and rotor distortion under all operating conditions.

809 Indicators for determining the axial position of rotors relative to their casings and for showing the longitu-

dinal expansion of casings at the sliding feet, if fitted, are to be provided for main turbines. The latter indicators should be fitted at both sides and be readily visible.

- 810 Pipes and ducts connected to turbine casings are to be so designed that no excessive thrust loads or moments are applied by them to the turbines. Gratings and any fittings in way of sliding feet or flexible-plate supports are to be so arranged that casing expansion is not restricted. Where main turbine seatings incorporating a tank structure are proposed, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.
- 811 In arranging the gland-sealing system the pipes are to be made self-draining and every precaution is to be taken against the possibility of condensed steam entering the glands and turbines. The steam supply to the gland-sealing system is to be fitted with an effective drain trap. In the air ejector re-circulating water system the connection to the condenser is to be so located that water cannot impinge on the L.P. rotor or casing.
- 812 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts of the turbine. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings. Drainage openings from oil baffles are to be amply large.
- 813 Discs of built rotors fitted by shrinking are to be secured with keys, dowels or other approved means in main turbines.
- 814 Smooth fillets are to be provided at abrupt changes of section of rotors, spindles, discs, blade roots and tenons. The rivet holes in blade shrouds are to be rounded and radiused on top and bottom surfaces and tenons to be radiused at junction with blade tips. Balancing holes in discs are to be well rounded and polished.
- 815 Surveyors are to be satisfied as to the workmanship and riveting of blades to shroud bands and that the blade tenons are free from cracks, particularly with high tensile blade material. Test samples are to be sectioned and examined and pull-off tests made if considered necessary by the Surveyors.
- 816 All rotors, as finished-bladed and complete with half-coupling, are to be dynamically balanced to the Surveyor's satisfaction in a machine of sensitivity appropriate to the size of rotor.
- 817 The turning gear for all propulsion turbines is to be power-driven and, if electric, is to be continuously rated.

Welded Components

- 818 Turbine rotors, cylinders and associated components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of equivalent standards, for rotor and cylinders respectively, to those required by the Rules for Class 1 and Class 2/1 Welded Pressure Vessels. See J 4.
- 819 Materials used in the construction of turbine rotors, cylinders, diaphragms, condensers, etc., are to be of welding quality.
- 820 Where it is proposed to construct rotors from two or more forged components joined by welding, full details of the chemical composition, mechanical properties and heat treatment of the materials, together with electrode particulars, an outline of the welding procedure, method of fabrication and heat treatment are to be submitted for consideration.
- 821 Joints in rotors and major joints in cylinders are to be designed as full-strength welds and for complete fusion of the joint.
- 822 In the first instance and before work is commenced the Surveyors are to be satisfied that the desired quality of welding is attainable with the proposed welding procedure, and for this purpose test specimens representative of the welded joints are to be provided for radiographic examination and mechanical tests. For cylinders the mechanical tests of butt joints are to include tensile, bend and nicked bend tests as detailed in J 4. For diaphragms, nozzle plates etc., representative samples are to be sectioned and macroetched. For rotors the mechanical tests are to include tensile (all weld metal), tensile (joint), bend (transverse), bend (longitudinal) and macro tests as detailed in J 4 or such other tests as may be approved. In subsequent production, check mechanical tests are to be carried out at the Surveyors' discretion if the quality of the welding is found to be unsatisfactory.
- 823 Adequate preheating is to be employed for mild steel cylinders and components where the metal thickness exceeds 44 mm (1.75 in) and for all low alloy steel cylinders and components and for any part where necessitated by joint restraint.
- 824 Stress relief heat treatment is to be applied to all cylinders and associated components on completion of the welding of all joints and attached structures. (See J 440 for details of stress relief procedure, temperature and duration).

- 825 The heat treatment of welded rotors is to be carried out as approved.
- 826 Examinations by non-destructive methods are to be made of all cylinders and rotors on completion of heat treatment as follows:—

CYLINDERS.—Major stressed joints in pressure shells are to be radiographed if practicable; other joints such as nozzle plate and branch pipe connections and diaphragm joints are to be examined by crack detection methods.

ROTORS.—All joints are to be examined by radiography or other approved methods and by magnetic crack detection methods.

827 The whole of the welding work is to be to the satisfaction of the Surveyors.

Governors and other Safety Devices

- 828 An overspeed protective device is to be provided for main and auxiliary turbines so as to shut off the steam automatically and prevent the maximum designed speed being exceeded by more than 15 per cent.
- 829 Where two or more propulsion turbines are coupled to the same main gear wheel and one overspeed protective device is provided, this is to be fitted to the L.P. ahead turbine. Hand trip gear for shutting off the steam in an emergency is to be provided at the manœuvring platform.
- 830 Arrangements are to be made for the steam to the ahead propulsion turbines to be automatically shut off in the event of failure of the lubricating oil pressure; steam is, however, to be made available at the astern turbine for braking purposes in such an emergency. See E 905 for emergency oil supply.
- 831 Where a turbine installation incorporates a reverse gear, electric transmission or reversible propeller, a speed governor in addition to, or in combination with, the overspeed protective device is to be fitted and is to be capable of controlling the speed of the unloaded turbine without bringing the overspeed protective device into action.
- 832 Auxiliary turbines intended for driving electric generators are to be fitted with speed governors which, with fixed setting, are to control the speed within the following limits:—

10 per cent momentary variation and 5 per cent permanent variation in speed when full load is suddenly

- taken off or put on, but for any a.c. installation the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of \pm 0,5 per cent.
- 833 Sentinel relief valves are to be provided at the exhaust ends or other approved positions of all main turbines and the valve discharge outlets are to be visible and suitably guarded if necessary. Where a low vacuum cut-out valve is provided the sentinel relief valve at the L.P. exhaust may be omitted.
- 834 Non-return valves or other means, which will prevent steam and water returning to the turbines, are to be fitted in bled steam connections.
- 835 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines, or alternatively at the inlets to the manœuvring valves.

Emergency Arrangements

- 836 In single screw ships fitted with turbines having more than one cylinder, the arrangements are to be such that steam can be led direct to the L.P. turbine and either the H.P. or I.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these emergency conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.
- 837 Ships intended for unrestricted service, fitted with steam turbines and having a single main water tube boiler, are to be provided with means to ensure emergency propulsion in the event of failure of the main boiler.

Hydraulic Tests

838 Manœuvring valves are to be tested to twice the working pressure. The nozzle boxes of impulse turbines are to be tested to 1,5 times the working pressure.

The cylinders of all turbines are to be tested to 1,5 times the working pressure in the casing or to 2 kg/cm² (30 lb/in²), whichever is the greater.

For test purposes the cylinders may be sub-divided with temporary diaphragms for distribution of test pressures.

Condensers are to be tested in the steam space to 1 kg/cm² (15 lb/in²). The water space is to be tested to the maximum pressure which the pump can develop with the discharge valve closed plus 0,7 kg/cm² (10 lb/in²), with a minimum test pressure of 2 kg/cm² (30 lb/in²). Where the operating conditions are not known, the test pressure is to be not less than 3,5 kg/cm² (50 lb/in²). See E 802.

Astern Power

839 Sufficient astern power is to be provided to maintain control of the ship in all normal circumstances.

The astern turbines are to be capable of maintaining in free route astern 70 per cent of the ahead revolutions, corresponding to the maximum propulsion shaft horse power for which the machinery is to be classed, for a period of at least 30 minutes without undue heating of the ahead turbines and condensers.

Trials

840 The sea trials are to be of sufficient duration to prove the machinery under power and normal manœuvring conditions. Where astern turbines or hydraulic reversing gear are fitted, astern running at 70 per cent of the full power ahead revolutions is to be demonstrated. The astern trial need only be of 15 minutes duration, but may be extended to 30 minutes at the Surveyors' discretion.

Where controllable pitch propellers are fitted the free route astern trial is to be carried out with the propeller blades set in the full astern position.

In the case of passenger ships, the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manœuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trials.

All trials are to be to the Surveyors' satisfaction.

Cross-references

841 Turbines intended for driving electric generators are to comply with the requirements of M 401 and M 402.

842 The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapter E.

843 For torsional vibrations of shafting, see H 243.

844 For lists of spare gear to be carried, see Chapter K.

Section 9

GENERAL REQUIREMENTS FOR GAS TURBINES

Scope

901 The following requirements are applicable to gas turbines for main propulsion and, where powers exceed 150 shp, to those for essential auxiliary services. The requirements do not apply to exhaust gas turbo blowers.

Plans

902 The following plans are to be submitted for consideration, together with particulars of materials and the maximum shaft horse power and revolutions per minute (see H 105). The rating as defined in H 105 (a) and (b) is to be taken at standard ambient conditions, viz.,

15°C (59°F) inlet air temperature, 1 kg/cm² (14·7 lb/in²) absolute pressure and, where applicable, a cooling water temperature of 15°C (59°F).

Curves should be submitted indicating the variation in performance with ambient conditions and the rating at the temperatures referred to in H 106, should be stated. The pressures and temperatures at maximum shaft horse power are to be indicated on the plans, where applicable.

- 1. Sectional assembly.
- 2. Casings.
- 3. Combustion chambers and heat exchangers.
- 4. Rotors, including blades, and couplings.
- Fuel oil systems, including controls and safety devices.
- 6. Lubricating oil systems.

Plans 5 and 6 are to be diagrammatic.

For additional machinery plans, where applicable, see G 104.

Materials

903 In addition to the requirements of H 101, particulars of chemical composition and room temperature mechanical properties of the materials are to be submitted for consideration. Details are also to be submitted, where applicable, of high temperature characteristics of the materials including, at the working temperatures, the associated creep rate and rupture strength for the designed service life, fatigue strength, corrosion resistance and scaling properties. Particulars of heat treatment, including stress relief, where applicable, are to be submitted.

Design Basis

904 Calculations of the steady state stresses, including the effect of stress raisers, etc., in the turbine and compressor rotors and blading at the maximum speed and temperature in service are to be submitted for consideration. Such calculations should indicate the designed service life and be accompanied, where possible, by test results substantiating the limiting criteria.

Details of calculations and tests to establish the service life of other stressed parts, including gearing where applicable, bearings, seals, etc., are to be submitted. All calculations and tests should take account of all relevant environmental factors including particular type of service and fuels intended to be used.

Overhaul Life

905 The overhaul schedule recommended by the manufacturer is to be submitted for consideration.

Design and Construction

- 906 All parts of turbines, compressors, etc., are to have clearances and fits consistent with adequate provision for the relative thermal expansion of the various components. Special attention is to be given to minimizing casing and rotor distortion under all operating conditions.
- 907 The air-inlet system is to be designed to minimize the entrance of harmful foreign matter.
- 908 The arrangement of the turbine exhaust system is to be such as to prevent exhaust gases being drawn into the compressors.
- 909 Means for preventing the accumulation of salt deposits in the compressors and turbines are to be provided in installations intended for operation in marine atmospheres.
- 910 When it is intended to burn non-distillate fuels forming harmful deposits, adequate provision should be made for periodic removal of the deposits.
- 911 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.
- 912 Means are to be provided for indicating the temperature of the turbine inlet or exhaust gases and the compressor discharge air.
- 913 Consideration should be given to the need for containment, with a view to minimizing and localizing damage, in the event of rotor blade failure.

Balancing

914 All rotors, as finished-bladed and complete with half-coupling, are to be dynamically balanced to the Surveyors' satisfaction in a machine of sensitivity appropriate to the size of rotor.

Vibration

915 For torsional vibrations of shafting, see H 243.

916 For other vibrations, care is to be taken in the design and manufacture of turbine and compressor rotors, rotor discs and rotor blades to ensure freedom from undue vibration within the operating speed range. Calculations of the critical speeds giving full details of the basic assumptions are to be submitted for consideration. Where critical speeds are found by calculation to occur within the operating speed range, vibration tests may be requested in order to verify the calculations.

Welded Components

- 917 Components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of the standards appropriate to the components according to the relevant paragraphs of J 4 and J 5.
- 918 In the first instance and before work is commenced, the Surveyors are to be satisfied that the desired quality of welding is attainable with the proposed welding procedure, and for this purpose test specimens representative of the welded joints are to be provided for radiographic examination and mechanical tests as required by H 822 for steam turbines.

In subsequent production, check mechanical tests are to be carried out at the Surveyors' discretion if the quality of the welding is found to be unsatisfactory.

- 919 Major joints are to be designed as full-strength welds and for complete fusion of the joint.
- 920 Stress relief heat treatment is to be applied to all cylinders, rotors and associated components on completion of the welding of all joints and attached structures. See J 440.
- 921 Before work is commenced, manufacturers are to submit for consideration their proposals for routine examination of joints by non-destructive means.
- 922 The whole of the welding work is to be to the satisfaction of the Surveyors.

Installation

923 Pipes and ducting connected to casings are to be so designed that no excessive thrust loads or moments are applied by them to the compressors and turbines, see also 906.

Platform gratings and fittings in way of the supports are to be so arranged that casing expansion is not restricted.

Where main turbine seatings incorporating a tank structure are proposed, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

Starting

924 The starting arrangements and starting air pipe systems and safety fittings are to comply with the requirements of H 607 to H 611, where applicable.

925 Means are to be provided, preferably automatic or interlocked, to clear all parts of the gas turbine of the accumulation of liquid fuel, or for purging gaseous fuel, before ignition commences on starting, or recommences after failure to start.

Governors and Other Safety Devices

926 An overspeed protective device is to be provided for each shaft of main and auxiliary turbines so as to shut off the fuel automatically near the burners, to prevent a dangerous overspeed condition of the shaft, except where it can be established that such a condition cannot arise.

The overspeed device should normally be set to operate when the speed of the line exceeds the rated maximum speed by 10 per cent. For auxiliary turbines driving electric generators this setting may be increased to 15 per cent.

927 Where a main propulsion installation incorporates a reverse gear, electric transmission or controllable (reversible) pitch propeller, a speed governor, independent of the overspeed protective device, is to be fitted and is to be capable of controlling the speed of the unloaded power turbine without bringing the overspeed protective device into action.

928 Where an auxiliary turbine is intended for driving an electric generator, a speed govenor, independent of the overspeed protective device, is to be fitted which, with fixed setting, is to control the speed within the following limits:—

10 per cent momentary variation and 5 per cent permanent variation in speed when full load is suddenly taken off or put on, but for any a.c. installation the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of ± 0.5 per cent.

929 Arrangements are to be made in main turbines to shut off the fuel automatically, near the burners, in the event of failure of the lubrication system. See E 905 for emergency oil supply.

Hand trip gear for shutting off the fuel in an emergency is to be provided at the manœuvring platform.

930 In addition, details of the manufacturer's proposed automatic safety devices to safeguard against hazardous conditions arising in the event of malfunctions in

the installation are to be submitted, together with details of fault analysis.

Hydraulic Tests

931 All casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be sub-divided with temporary diaphragms for distribution of test pressure.

Where hydraulic tests cannot be carried out, the manufacturers are to submit for approval alternative proposals for determining the soundness of the component.

932 Intercoolers and heat exchangers are to be tested to 1,5 times the maximum working pressure on each side separately.

Overspeed Tests

933 Before installation, the gas turbine is to be tested for 5 minutes at 5 per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

Where it is impracticable to overspeed the complete installation, each rotor, completely bladed and with all relevant parts such as half-couplings, shall be overspeedtested individually at the appropriate speed.

Shop Trials

934 The manufacturer's proposals for testing the gas turbine are to be submitted for approval.

Alternative Survey Procedure for Line Production

935 Consideration will be given to the adoption of a system of examination involving periodic inspection of the works instead of survey of each individual component. See G 108.

For this purpose, full details of the manufacturer's procedures for quality control and schedule of tests are to be submitted for approval. The Surveyors may require supplementary tests.

Astern Power

936 In installations where gas turbines are employed for main propulsion, sufficient astern power is to be provided to maintain control of the ship in all normal circumstances and of maintaining, in free route astern, 70 per cent of the ahead revolutions corresponding to the maximum propulsion shaft horse power for which the machinery is to be classed.

Sea Trials

937 The sea trials are to be of sufficient duration to prove the machinery at the horse power for which the machinery is to be classed and under normal manœuvring conditions, also to demonstrate that any vibration which may occur within the operating speed range is acceptable.

The ability of the installation to permit astern running at 70 per cent of the full power ahead revolutions without adverse effects is to be demonstrated. The astern trial need only be of 15 minutes duration, but may be extended to 30 minutes at the Surveyors' discretion.

Where controllable pitch propellers are fitted the free route astern trial is to be carried out with the propeller blades set in the full astern position.

In the case of passenger ships, the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manœuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trials.

The ability of the means for starting the installation to provide not less than six consecutive starts is to be demonstrated.

All trials are to be to the Surveyors' satisfaction.

938 The spare gear for gas turbines has not been indicated in view of the variation in turbine design and service conditions. In the circumstances, a list of proposed spare gear is to be submitted for consideration.

Cross-references

939 Gas turbines intended for driving electric generators are also to comply with the requirements of M 401 and M 402.

940 The piping systems and lubricating oil systems are, in general, to comply with the requirements of Chapter E, due regard being paid to the particular type of installation.

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Chapter J

BOILERS AND OTHER PRESSURE VESSELS

General

The requirements of this Chapter are applicable to fired and unfired pressure vessels of seamless, fusion welded, and riveted construction, intended for marine services.

The pressure vessels are to be made in accordance with the requirements contained in the following sections, where applicable:—

Section 1. General Requirements,

- , 2. Design,
- ,, 3. Construction,
- " 4. Requirements for Fusion Welding,
- , 5. Manufacture and Workmanship,
- ,, 6. Mountings and Fittings,
- Pressure Vessels for the Carriage of Liquefied Petroleum Gases,
- " 8. Riveted Pressure Vessels.

Seamless pressure vessels are to be manufactured in accordance with the requirements of Chapter Q 6 or Q 7 where applicable, and tested by hydraulic pressure as for fusion welded pressure vessels (see J 445).

Section 1

GENERAL REQUIREMENTS

Design Pressure

101 The design pressure is the maximum permissible working pressure and is not to be less than the highest set pressure of any safety valve. The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure adjusted, where necessary, to take account of pressure variations corresponding to the most severe operational conditions.

Note. It is desirable that there should be a margin between the normal pressure at which the boiler or pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

Metal Temperature

102 The metal temperature "t", used to evaluate the allowable stress "f", is to be taken as the actual metal temperature expected under operating conditions for the pressure part concerned and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration. The following values are to be regarded as minimum subject to the overriding provision that "t" is not to be less than 250°C (482°F) and 100°C (212°F) in the case of fired and unfired pressure vessels respectively.

- (1) For unfired pressure vessels and for the following parts of fired pressure vessels, viz., shells, drums or other pressure components not heated by hot gases and those parts adequately protected by insulation from hot gases, "t" is to be taken as the maximum temperature of the internal fluid.
- (2) For pressure parts heated by hot gases, "t" is to be taken as not less than 25degC (45degF) in excess of the maximum temperature of the internal fluid.

In general, where any parts of boiler drums or headers are not protected by tubes and are exposed to radiation from the fire, or to the impact of hot gases, they are to be protected by a shield of good refractory materials or by other approved means.

Drums and headers of thickness greater than 30 mm (1·2 in) are not to be exposed to combustion gases having an anticipated temperature in excess of 650°C (1200°F) unless they are efficiently cooled by closely arranged tubes accommodated therein.

- (3) For boiler, superheater, reheater and economiser tubes "t" is to be taken as indicated in J 222.
- (4) For combustion chambers of the type used in horizontal wet-back boilers, "t" is to be taken as not less than 50degC (90degF) in excess of the maximum temperature of the internal fluid.
- (5) For furnaces, fireboxes, rear tube plates of dry-back boilers and pressure parts subject to similar rates of heat-transfer, "t" is to be taken as not less than 90degC (162degF) in excess of the maximum temperature of the internal fluid.

Materials

103 Materials used in the construction of boilers and other pressure vessels are to be manufactured and tested in accordance with the requirements of Chapter Q.

Rolled steel plates are subject to the limitations of application indicated in Table J 1.1, and for approval purposes the grades of plates specified in Q 3 have been grouped as follows:—

Group 1 Carbon and carbon manganese steels 37 to 57 kg/mm² (23·5 to 36·2 ton/in²).

Group 2 Carbon and carbon manganese steels 52 to 62 kg/mm² (33 to 39·4 ton/in²).

Group 3 Low alloy steels.

As an alternative to the materials stated in Chapter Q consideration will be given to the use or:—

- (a) Materials complying with national or proprietary specifications which give reasonable equivalence to the requirements of Chapter Q, or
- (b) materials which have higher carbon content or alloy steels not specified in Chapter Q

provided in both cases details of the chemical composition, heat treatment and mechanical properties are submitted for approval.

Where materials, other than those specified in Chapter Q are proposed, the values of the properties to be used for deriving the allowable stress are to be subject to agreement by the Society.

Plans

104 Plans in triplicate of boilers, superheaters and economisers are to be submitted for consideration, as required by G 104. When plans of water tube boilers are submitted for approval particulars of the safety valves and their disposition on boiler and superheater, together with the estimated pressure drop through the superheater, are to be stated. The pressures proposed for the settings of boiler and superheater safety valves are to be indicated on the boiler plan.

In the case of fusion welded pressure vessels plans in triplicate, showing full constructional features of the vessel and dimensional details of the weld grooves for longitudinal and circumferential seams and attachments, together with particulars of the electrodes and of the mechanical properties of the materials are to be submitted before construction is commenced.

Allowable Stress

105 The term "allowable stress", designated by "f" in the following paragraphs, is the stress to be used in the formulæ for the calculation of scantlings of pressure parts.

The allowable stress "f" is the lowest of the following values; the material properties for the appropriate category, grade and tensile range of steel are indicated in Chapter Q.

Wrought Steel

$$\begin{array}{ll} \text{Fired Pressure Vessels} & f = \frac{E_t}{1,6} & f = \frac{R_{20}}{2,7} & f = \frac{S_R}{1,5} \\ \\ \text{Unfired Pressure Vessels} & f = \frac{E_t}{1,5} & f = \frac{R_{20}}{2,7} & f = \frac{S_R}{1,5} \\ \end{array}$$

TABLE J 1.1

Application	Group of Steel	Tensile Strength limited to
Welded Pressure Vessels Class 1	1 2 3	THE STREET LANSING
Welded Pressure Vessels Class 2/1	1 2	
Welded Pressure Vessels Class 2/2	1	37–52 kg/mm ² (23·5–33 ton/in ²)
Welded Pressure Vessels Class 3	1	37-52 kg/mm ²
		(23·5-33 ton/in²)
Boiler furnaces, combustion chambers and	1 2	42-62 kg/mm ²
flanged plates	discould of the	(26·7-39·4 ton/in²)
Shells of all riveted boilers	1	42-57 kg/mm ²
		(26·7-36·2 ton/in²)
Shells of riveted boilers with welded com-	1	42-52 kg/mm ²
pensating rings and attachments.		(26·7-33 ton/in²)

where $E_{\rm t}={
m specified\ minimum\ lower\ yield\ stress\ or\ 0,2\ per}$ cent proof stress at temperature "t",

R₂₀ = specified minimum tensile strength at room temperature,

S_R = average stress to produce rupture in 100 000 hours at temperature "t",

t = metal temperature (see 102).

The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated above using the appropriate values for cast steel.

Where steel castings, which have been tested in accordance with Q 5 are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to above. Particulars of the non-destructive test proposals are to be submitted for consideration.

Joint Factors

106 Fusion welded pressure parts are to be made in accordance with J 4 and the following joint factors are to be used in the equations in J 2 where applicable.

Class of Welding	Joint Factor		
Class 1	1,0		
Class 2/1	0,85		
Class 2/2	0,75		
Class 3	0,60		

The longitudinal joints for all classes of vessels are to be butt joints. Circumferential joints for Classes 1, 2/1 and 2/2 vessels are to be butt joints and for Class 3 vessels may be either butt joints or lap joints.

Where a pressure vessel is to be made of alloy steel and where the scantlings have been approved on the basis of the high temperature properties of the material, particulars of the electrodes to be used including typical mechanical properties and chemical composition of the deposited weld metal are to be submitted for approval.

Classification of Fusion Welded Pressure Vessels

107 For Rule purposes pressure vessels are graded as follows:—

CLASS 1

Pressure parts of boilers and fired pressure vessels intended for design pressures above 3,5 kg/cm² (50 lb/in²). Pressure parts of steam heated steam generators where the design pressure exceeds 11,5 kg/cm² (165 lb/in²), or where the design pressure, in kg/cm² (lb/in²), multiplied by the internal diameter of the shell, in mm (in), exceeds 14 700 (8250).

Other pressure vessels where the shell thickness exceeds 38 mm (1.5 in).

Classes 2/1 and 2/2

Pressure parts of boilers and fired pressure vessels not included in Class 1.

Pressure parts of steam heated steam generators not included in Class 1.

Other pressure vessels where the design pressure exceeds 17,5 kg/cm² (250 lb/in²), or the metal temperature exceeds 150°C (300°F), or where the design pressure, in kg/cm² (lb/in²), multiplied by the actual thickness of the shell, in mm (in), exceeds 160 (90).

Maximum shell thickness 38 mm (1.5 in).

CLASS 3

Pressure vessels not included in Classes 1, 2/1 and 2/2. Maximum shell thickness 16 mm (0.625 in).

Pressure vessels which may be constructed in accordance with Classes 2/1, 2/2 or 3 standards, as indicated above, will, if manufactured in accordance with the requirements of a superior class, be approved with the scantlings appropriate to that class.

In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc., it may be necessary to require that certain pressure vessels be manufactured in accordance with the requirements of a superior class.

Heat treatment, non-destructive and routine tests where required, for the four classes of pressure vessel are indicated in Table J 1.2 and details of these requirements are given in J 4.

TABLE J 1.2

Hydraulie Test	Routine Weld Tests	Heat Treatment	Radiographic Examination	Class
required	required	see J 439	required see J 420(a)	1
required	required	see J 439	spot required see J 420(b)	2/1
required	required	see J 439	-	2/2
required		_		3

Pressure Parts of Irregular Shape

108 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of the formulæ in J 2, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by an agreed alternative method.

General

consideration may require to be given to increasing the scantlings derived from the formulæ, e.g. by increasing the corrosion or other allowance at present shown in the formulæ or adopting a design pressure higher than defined in 101, so as to offset the possible reduction of life in service caused by the adverse conditions. In this connection, where necessary, account should also be taken of any excess of loading resulting from:—

- (1) Impact loads, including rapidly fluctuating pressures,
- (2) Weight of the vessel and normal contents under operating and test conditions,
- (3) Superimposed loads such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping,
- Reactions of supporting lugs, rings, saddles or other types of supports,
- (5) The effect of temperature gradients on maximum stress.

Design Symbols

110 The symbols used in the various formulæ in J 2, unless otherwise stated, are as defined below and are applicable to the specific part of the pressure vessel under consideration.

- CANDAGE OF CASE		
T = minimum thickness	Metric units mm	(British units) (in)
P = design pressure	kg/cm²	(lb/in²)
D _i = inside diameter	mm	(in)
Do = outside diameter	mm	(in)
R _i = inside radius	mm	(in)
R _o = outside radius	mm	(in)
r _i = inside knuckle radius	mm	(in)
r _o = outside knuckle radius	mm	(in)
p = pitch	mm	(in)
d = diameter of hole or opening	mm	(in)
C = corrosion allowance	mm	(in)
f = allowable stress	kg/cm ²	(lb/in^2)
J = joint factor applicable to welded seams, or ligament efficiency between tube holes (expressed as a frac- tion)	peral to an many word? feetberger and pile to	off stream? Y NOT it at at and, solderlings
t = design temperature	°C	(°F)

Section 2

DESIGN

SEAMLESS AND FUSION WELDED CYLINDRICAL SHELLS, DRUMS AND HEADERS SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

201 The minimum thickness, T, of a cylindrical shell is to be determined by the following formula:—

$$T = \frac{P R_i}{fJ - 0.5P} + 0.75 \text{ mm} \quad \left(T = \frac{P R_i}{fJ - 0.5P} + 0.03 \text{ in}\right)$$

where T, P, R, and f are as defined in J 110.

J = efficiency of ligaments between tube holes or other openings in the shell or the joint factor of the longitudinal joints (expressed as a fraction). See
 J 106, 202 to 205, whichever applies. In the case of seamless shells clear of tube holes or other openings J = 1,0.

The above formula is only applicable where the resulting thickness does not exceed half the internal radius, i.e. where R_0 is not greater than 1,5 R_i .

Irrespective of the thickness determined by the above formula, T is not to be less than:—

- (a) for unfired pressure vessels 5 mm (0.197 in),
- (b) for drum shell plates of fired pressure vessels, which are unpierced by tube holes 9,5 mm (0·375 in) (see Note),
- (c) for tube plates, such thickness as may be necessary to allow a minimum parallel belt width of tube seat of 9,5 mm (0·375 in) or such greater width as may be necessary to ensure tube tightness. See J 313.

NOTE. In special cases where it is proposed to use a shell thickness less than in (b), the proposal will be the subject of special consideration.

Efficiency of Ligaments between Tube Holes

202 Where tube holes are drilled in a cylindrical shell in a line or lines parallel to its axis the efficiency J of the ligaments is to be determined as follows:—

(a) Regular drilling. Where the distance between adjacent tube holes is constant, see Fig. J 2.1,

$$J = \frac{p - d}{p} \tag{1}$$

where p = pitch of tube holes, in mm (in),

d = the mean effective diameter of the tube holes, in mm (in), after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub, see 203 and 206.

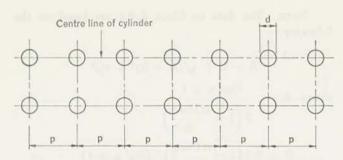


Fig. J 2.1 REGULAR DRILLING

(b) Irregular drilling. Where the distance between centres of adjacent tube holes is not constant (see Fig. J 2.2),

$$J = \frac{p_1 + p_2 - 2d}{p_1 + p_2} \tag{2}$$

where p₁ = the shorter of any two adjacent pitches, in mm (in),

p₂ = the longer of any two adjacent pitches, in mm (in),

d = the mean effective diameter of the tube holes in mm (in), after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub (see 203 and 206).

When applying formula (2) the double pitch (p_1+p_2) chosen is to be that which makes J a minimum and in no case is p_2 to be taken as greater than twice p_1 .

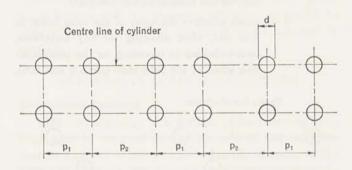


Fig. J 2.2 IRREGULAR DRILLING

Compensating Effect of Tube Stubs

203 Where a drum or header is drilled for tube stubs fitted by strength welding either in line or in staggered formation, the effective diameter of the holes is to be taken

as
$$d_e = d_a - \frac{A}{T}$$
 (1)

where d_e = the equivalent diameter of the hole, in mm (in),

da = the actual diameter of the hole, in mm (in),

T = the thickness of the shell, in mm (in),

A = the compensating area provided by each tube stub and its welding fillets, in mm² (in²).

The compensating area A is to be measured in a plane through the axis of the tube stub parallel to the longitudinal axis of the drum or header and is to be calculated as follows (see Figs. J 2.3 and J 2.4):—

- (i) The sectional area of the stub, in excess of that required by 222 for the minimum tube thickness, from the interior surface of the shell up to a distance "b" from the outer surface of the shell (see Notes 1 and 2);
- (ii) plus the sectional area of the stub projecting inside the shell within a distance "b" from the inner surface of the shell (see Note 2);
- (iii) plus the sectional area of the welding fillets inside and outside the shell:—

where
$$b = \sqrt{d_a t_a}$$
 (2)

ta = actual thickness of the tube stub, in mm (in).

Calculated minimum thickness to satisfy J 222

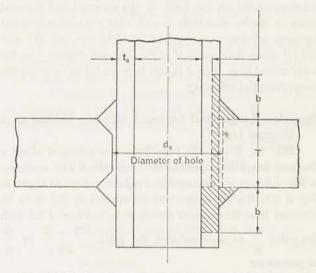


Fig. J 2.3 Compensation of Welded Tube Stubs

Area A equals twice the area shown cross-hatched

Note 1. In the case of a set-on stub (see Fig. J 2.4) the compensation extends from the outer surface of the shell only.

Note 2. Where the material of the tube stub has an allowable stress different from that of the shell the compensating sectional area of the stub is to be multiplied by the ratio:—

allowable stress of stub at design metal temperature allowable stress of shell at design metal temperature

Calculated minimum thickness to satisfy J 222

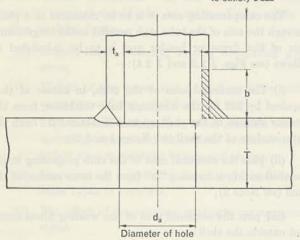


Fig. J 2.4 Compensation of Welded Tube Stubs

Area A equals twice the area shown cross-hatched

Circumferential Ligaments

204 Where the circumferential pitch between tube holes measured on the mean of the external and internal drum or header diameters is such that the circumferential ligament efficiency determined by formulæ 202 (1) and 202 (2) is less than one-half of the ligament efficiency on the longitudinal axis, then J in 201 is to be taken as twice the circumferential efficiency.

Equivalent Longitudinal Ligament Efficiency Drilling on a Diagonal Line

205 (a) Where the tube holes are arranged along a diagonal line with respect to the longitudinal axis as shown in Fig. J 2.5, or are arranged in a regular pattern as shown in Fig. J 2.6, the efficiency J to be applied in 201 is to be obtained from the series of curves given in Chart J 2.1 with the ratio $\frac{b}{a}$ as abscissa and the ratio $\frac{2a-d}{2a}$ or $\frac{d}{a}$ as parameter

where a and b as shown in Figs. J 2.5 and J 2.6, are measured in mm (in) on the median line of the plate.

d = mean effective diameter of the tube holes, in mm (in), after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub (see 203 and 206). Note. The data on Chart J 2.1 are based on the following:-

where
$$A = \frac{2}{A + B + \sqrt{(A - B)^2 + 4C^2}}$$

$$B = 0.5 \left(1 - \frac{d \cos \alpha}{a}\right)$$

$$C = \frac{\sin \alpha \cos \alpha}{2\left(1 - \frac{d \cos \alpha}{a}\right)} \quad (\sin^2 \alpha + 1)$$

$$C = \frac{\sin \alpha \cos \alpha}{2\left(1 - \frac{d \cos \alpha}{a}\right)}$$

$$\cos \alpha = \frac{1}{\sqrt{1 + \frac{b^2}{a^2}}}$$

$$\sin \alpha = \frac{1}{\sqrt{1 + \frac{a^2}{b^2}}}$$

where α = angle of centreline of cylinder to centreline of diagonal holes.

(b) Where there is regular staggered spacing of tube holes as shown in Fig. J 2.7, the smallest value of the efficiency J of all ligaments (longitudinal, circumferential and diagonal) is obtained from Chart J 2.2 with the ratio $\frac{b}{a}$ as abscissa and the ratio $\frac{2a-d}{2a}$ or $\frac{d}{a}$ as parameter where a and b as shown in Fig. J 2.7 are measured, in mm (in), on the median line of the plate,

d = mean effective diameter of the tube holes, in mm (in), after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub (see 203 and 206).

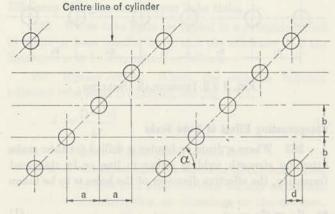


Fig. J 2.5 Spacing of Holes on a Diagonal Line

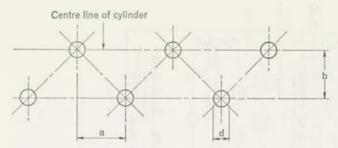


Fig. J 2.6 Regular Saw-Tooth Pattern of Holes

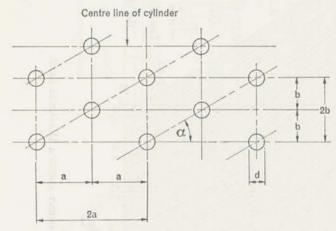


Fig. J 2.7 Regular Staggering of Holes

(c) Where tube holes are irregularly spaced along a drum or header, and do not come in a straight line, the formula 202 (2) is to apply except that an equivalent longitudinal width of the diagonal ligament is to be used. An equivalent longitudinal width is that width which gives, using formula 202 (1), the same efficiency as would be obtained using Chart J 2.1 for the diagonal ligament in question.

OPENINGS IN CYLINDRICAL SHELLS

Unreinforced Openings

206 (a) Openings in a definite pattern such as tube holes may be designed in accordance with the rules for ligaments in 202 to 205 provided that the diameter of the largest hole in the group does not exceed that permitted by (b) below.

(b) The maximum diameter "d" of any unreinforced opening is to be obtained from the curves in Chart J 2.3 or J 2.4.

In the Charts the value of K to be used is calculated from the following formula:—

$$K = \frac{PD_0}{1,82 fT}$$

where P, Do and f are as defined in J 110,

T = actual thickness of shell, in mm (in).

For elliptical or oval holes, "d" refers to the mean of the major and minor axes.

No unreinforced opening is to exceed 200 mm (7 \cdot 875 in) in diameter.

Reinforced Openings

207 Openings larger than those permitted by 206 are to be reinforced by the method shown in Fig. J 2.8. Compensation shall be considered adequate when the compensating area Y, Figs. J 2.8a and J 2.8b is equal to or greater than the area X requiring compensation.

Area X is to be calculated as the product of the inside radius of the standpipe and the thickness A which would be required for an equivalent seamless unpierced shell.

Area Y is to be measured in a plane through the axis of the standpipe parallel to the longitudinal axis of the drum and is to be calculated as follows:—

(i) For that part of the standpipe which projects outside the shell calculate the full sectional area of the stem up to a distance C from the actual outer surface of the shell plate and deduct from it the sectional area which the stem would have if its thickness were as calculated in accordance with 222.

(ii) Add to it the full sectional area of that part of the stem which projects inside the shell up to a distance C from the inside surface of the shell.

(iii) Add to it the sectional area of the fillet welds on both sides of the shell.

(iv) Add to it the area obtained by multiplying the difference between the actual shell thickness and the equivalent unpierced shell thickness A by a length D.

(v) If additional reinforcement is required to be fitted as illustrated in Fig. J 2.8b add also the sectional area of the reinforcement and the sectional area of its fillet welds.

The following notations are used in Fig. J 2.8:-

C in mm (in) is the lesser of 2,5 Ta

or $2,5 t_a + t_r$

D in mm (in) is the greater of 0,5 d or $T_a + 75$ mm $(T_a + 3$ in)

Ta = actual thickness of shell plate, in mm (in),

t_a = actual thickness of standpipe stem or branch, in mm (in),

t_r = thickness of added reinforcement, in mm (in), (t_r will be zero when there is no compensating plate on the side of the shell under consideration),

d = internal diameter of standpipe or branch, in mm (in).

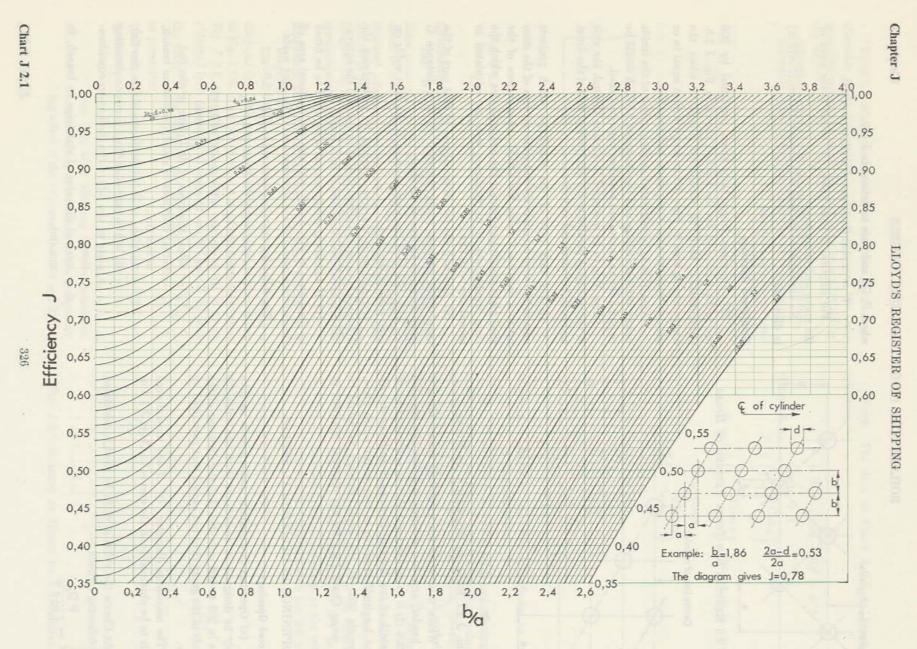


CHART J 2.1 EFFICIENCY OF LIGAMENT ALONG A DIAGONAL LINE

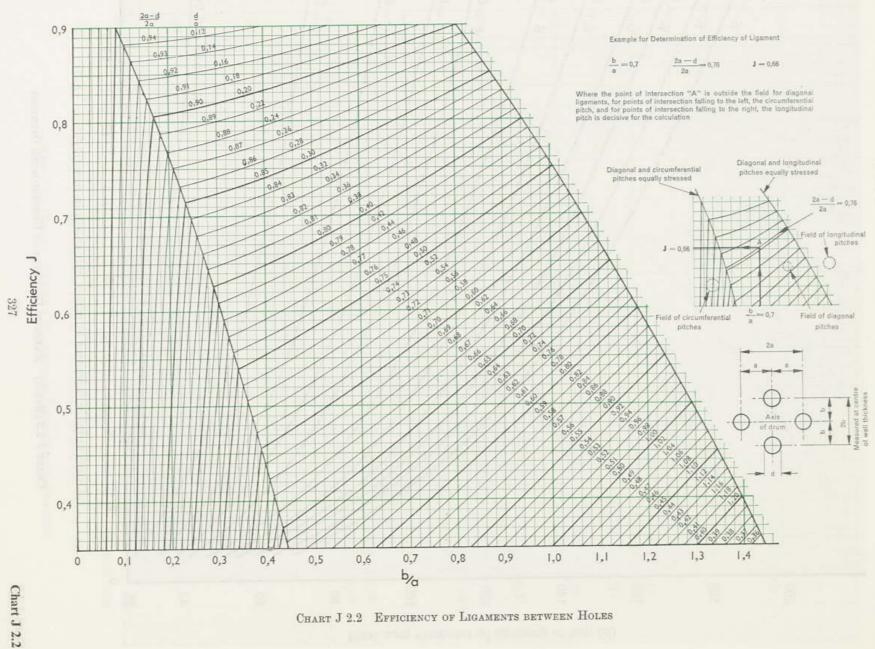


CHART J 2.2 EFFICIENCY OF LIGAMENTS BETWEEN HOLES

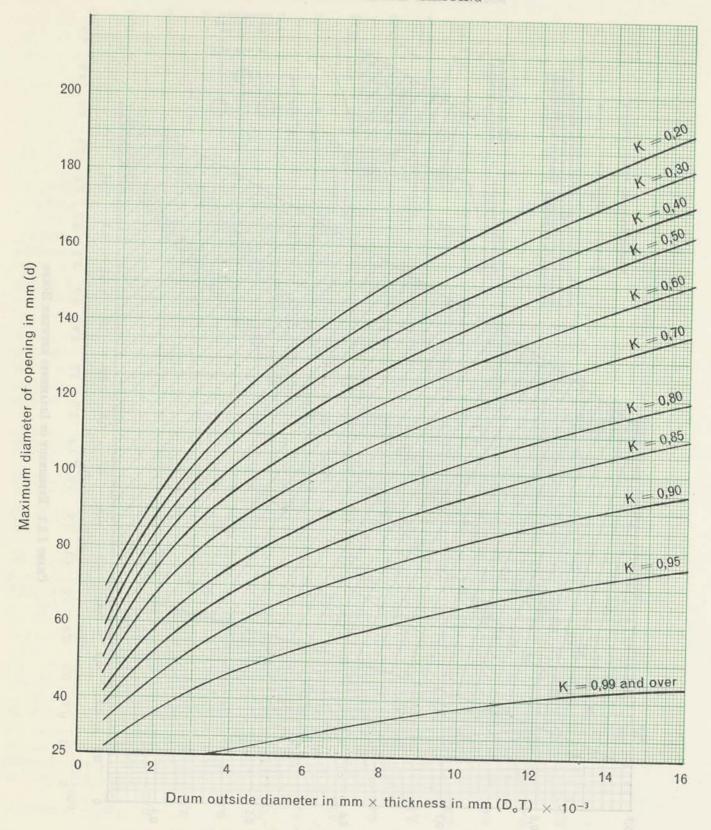
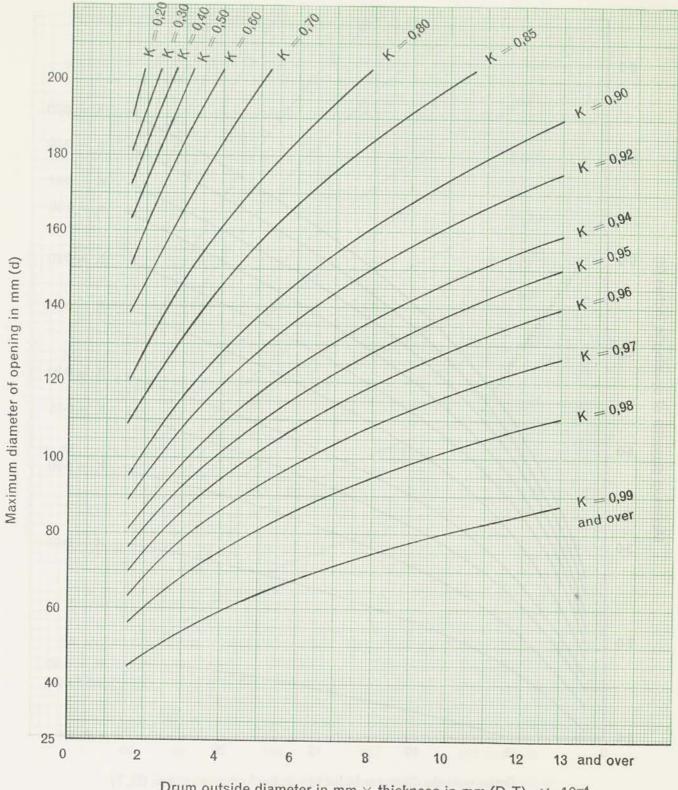
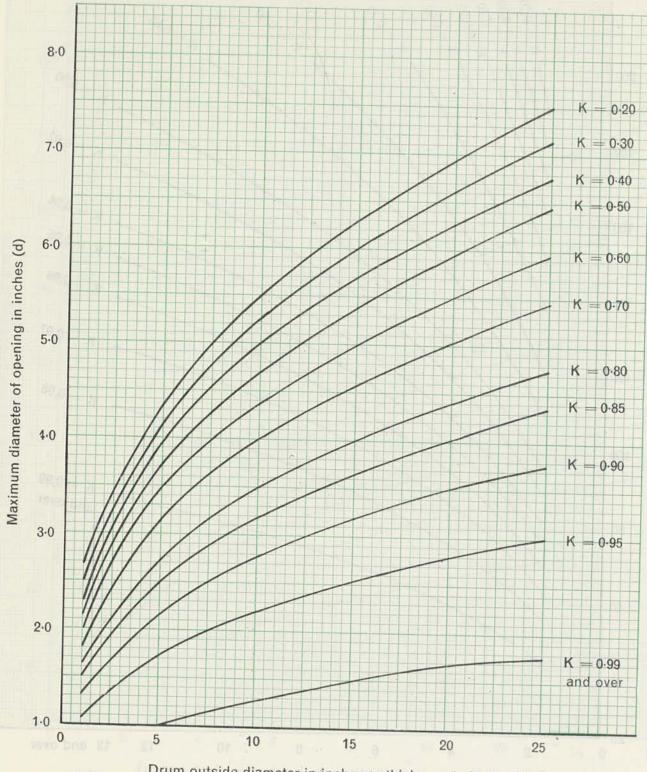


CHART J 2.3 (Metric) MAXIMUM DIAMETER OF UNREINFORCED OPENINGS



Drum outside diameter in mm \times thickness in mm (D $_{o}$ T) \times 10 $^{-4}$ Chart J 2.4 (Metric) Maximum Diameter of Unreinforced Openings



Drum outside diameter in inches \times thickness in inches (D_oT) Chart J 2.3 (British) Maximum Diameter of Unreinforced Openings

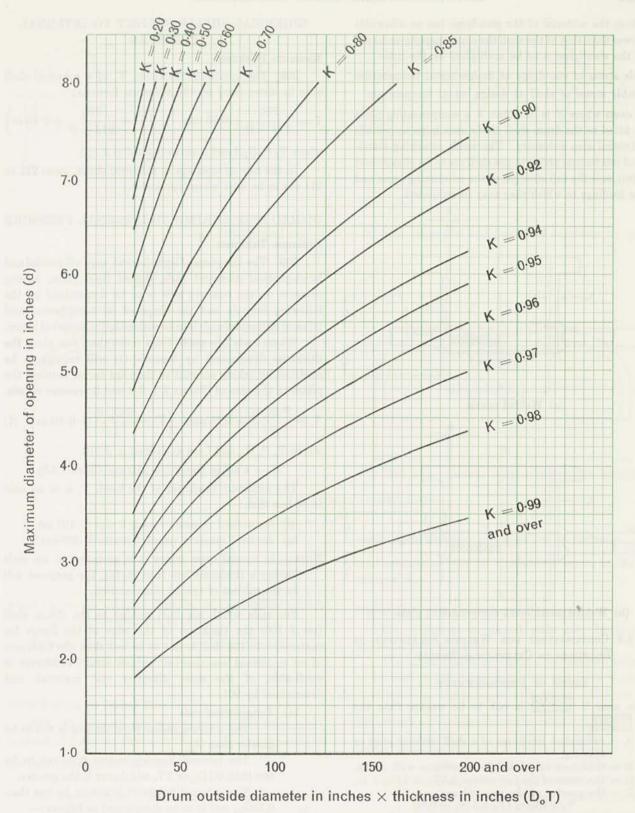
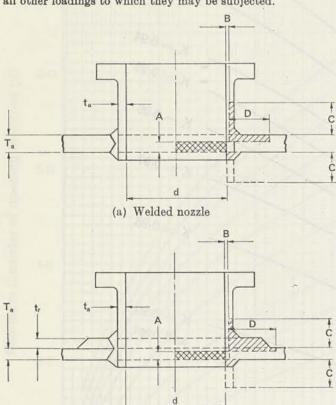


CHART J 2.4 (British) MAXIMUM DIAMETER OF UNREINFORCED OPENINGS

Where the material of the standpipe has an allowable stress lower than that of the shell the compensating sectional area of the standpipe is to be multiplied by the ratio allowable stress of standpipe at design metal temperature

allowable stress of shell at design metal temperature

In cases where Y is less than X a compensating plate is to be fitted to the drum shell at the standpipe to provide the additional area necessary. The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.



(b) Welded nozzle with compensating plate

Fig. J 2.8 Compensation for Welded Standpipes or Branches in Cylindrical Shells.

LIMITS OF REINFORCEMENT

The area Y is not to be weaker than the area X

where A = calculated thickness of a shell without joint or opening,

B = thickness calculated in accordance with J 222.

C =the lesser of the two values, 2,5 T_a or 2,5 $t_a + t_r$,

D = the greater of the two values:

 T_a+75 mm (T_a+3 in) or 0,5d.

Note. tr shall be equal to zero when there is no compensating plate on the side of the shell under consideration.

SPHERICAL SHELLS SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

208 The minimum thickness, T, of a spherical shell is to be determined by the following formula:—

$$T = \frac{PR_i}{2fJ - P} + 0.75 \,\text{mm} \qquad \left(T = \frac{PR_i}{2fJ - P} + 0.03 \,\text{in}\right)$$

where T, P, R_i, f and J are as defined in J 110.

In the case of openings in spherical shells, paras 211 to 214 are to be used where applicable.

DISHED ENDS SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

209 The thickness of torispherical, semi-ellipsoidal and hemispherical unstayed ends, dished from plate, having pressure on the concave side is to be determined by the following formula and the shape of (a) torispherical and (b) semi-ellipsoidal ends is to be within the limits stated below.

Where ends are made from more than one plate the thickness determined by formula (1) will require to be modified by taking account of the joint factor between the plates in the case of Classes 2/1, 2/2 and 3 pressure vessels.

$$T = \frac{PD_0K}{2f} + 0.75 \text{ mm} \left(T = \frac{PD_0K}{2f} + 0.03 \text{ in}\right)$$
 (1)

where T, P, Do and f are as defined in J 110,

K = a shape factor (see 210 and Chart J 2.5).

The minimum thickness of the head, T, is in no case to be less than:—

- (i) for unfired pressure vessels 5 mm (0.197 in).
- (ii) for fired pressure vessels 9,5 mm (0.375 in).

Note:—In special cases where it is proposed to use ends having a thickness less than in (ii), the proposal will be the subject of special consideration.

For ends which are butt welded to the drum shell (see J 106) the thickness of the edge of the flange for connection to the shell is not to be less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 201.

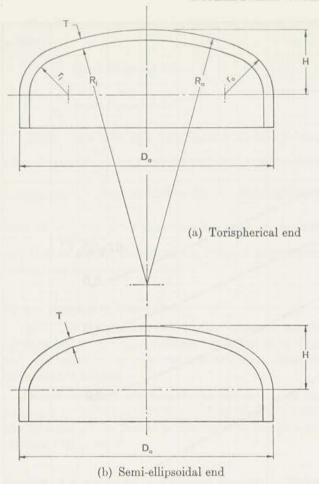
(a) Torispherical ends

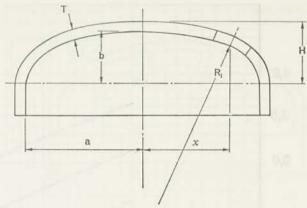
The internal radius R_i of dishing is not to be greater than D_0 .

The internal knuckle radius r_i is not to be less than $0.1D_0$ or 3T, whichever is the greater.

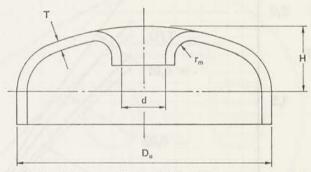
The external height H is not to be less than 0,18D_O, and is to be determined as follows:—

$$H = R_o - \sqrt{(R_o - 0.5 D_o) (R_o + 0.5 D_o - 2 r_o)}$$
 (2)





(c) Semi-ellipsoidal end (radius of curvature at opening)



(d) End with manhole (semi-ellipsoidal or torispherical)

Fig. J 2.9 Typical Dished Ends

(b) Semi-Ellipsoidal ends

The external height H is not to be less than $0.2~\mathrm{D}_\mathrm{O}$

where D_0 = the external diameter of the parallel portion of the end, in mm (in),

In both cases H is to be measured from the commencement of curvature (see Fig. J 2.9).

Shape Factors for Dished Ends

210 The shape factor K to be used in 209, formula (1), is obtained from the curves in Chart J 2.5 and depends on the ratio of height to diameter $\frac{\mathsf{H}}{\mathsf{D}_{\mathsf{G}}}$.

The lowest curve in the series provides the factor K for plain (i.e., unpierced) ends. Where the value $\frac{\mathsf{H}}{\mathsf{D}_0}$ is lower than 0,25 the value of K depends on the ratio of

thickness to diameter $\frac{T}{D_O}$ as well as on the ratio $\frac{H}{D_O}$ and a trial calculation may be necessary to arrive at the correct value of K.

Dished Ends with Unreinforced Openings

211 Openings in dished ends may be circular or approximately elliptical.

The upper curves on Chart J 2.5 provide values of K to be used in 209, formula (1), for ends with unreinforced openings (e.g., manholes or tube holes). The selection of

the correct curve depends on the value $\frac{d}{\sqrt{D_o T}}$

where d = the diameter of the largest opening in the end plate, in mm (in), (in the case of an elliptical opening, the larger axis of the ellipse),

 $T = minimum thickness, after dishing, in mm (in), <math>D_0 = outside diameter of dished end, in mm (in).$

Trial calculation is necessary in order to select the correct curve.

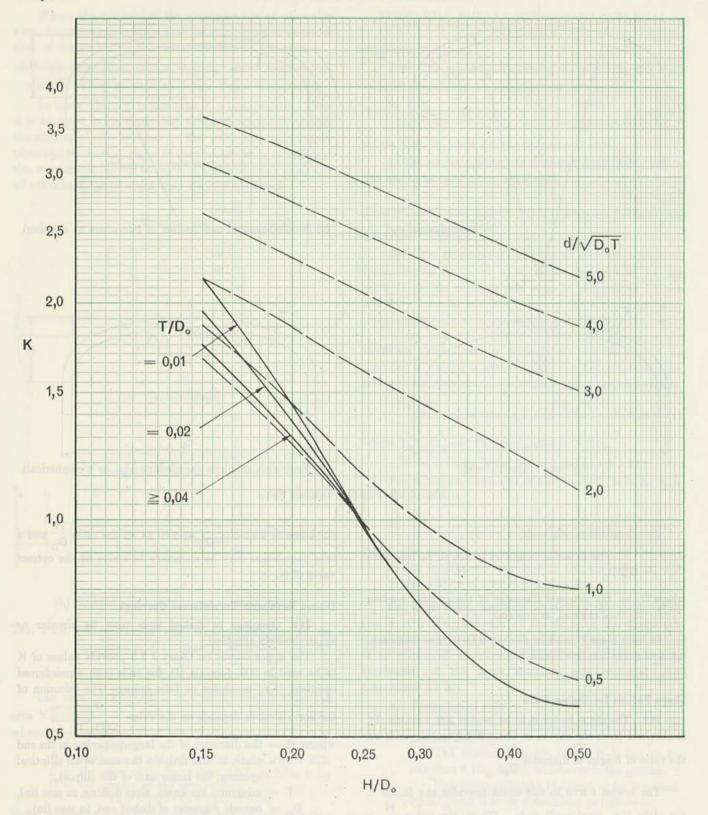


CHART J 2.5 SHAPE FACTOR

The following requirements must in any case be satisfied:—

$$\frac{T}{D_O}$$
 is not to exceed 0,1 $\frac{d}{D_O}$ is not to exceed 0,7.

Note. It will be seen from Chart J 2.5 that for any selected ratio of $\frac{\mathsf{H}}{\mathsf{D}_0}$, the curve for unpierced ends indicates a value for $\frac{\mathsf{d}}{\sqrt{\mathsf{D}_0\mathsf{T}}}$ as well as for K. Holes giving a value of $\frac{\mathsf{d}}{\sqrt{\mathsf{D}_0\mathsf{T}}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

Flanged Openings in Dished Ends

212 The requirements in 211 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

Where openings are flanged the radius $r_{\rm m}$ of the flanging is not to be less than 25 mm (1 in) (see Fig. J 2.9d). The thickness of the flanged portion may be less than the calculated thickness T.

Location of Unreinforced and Flanged Openings in Dished Ends

213 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. J 2.10. In Fig. J 2.10, d₂ is equal to the diameter of the smaller hole.

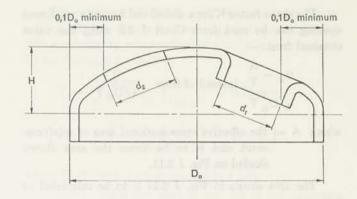
Dished Ends with Reinforced Openings

214 Where it is desired to use a large opening on a dished end of less thickness than would be required by the application of 211 reinforcement of the end is to be provided.

Reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods (see Fig. J 2.11). Forged reinforcements may be used.

Reinforcing material within the following limits may be taken as effective reinforcement.

(a) The effective width l₁ of reinforcement is not to exceed √2 R₁ T or 0,5d₀ whichever is the lesser.



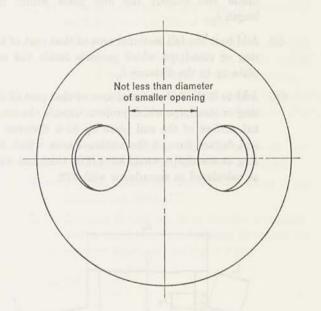


Fig. J 2.10 Openings in Dished Ends

(b) The effective length l_2 of a reinforcing ring is not to exceed $\sqrt{d_0 t_a}$

where R_i = the internal radius of the spherical part of a torispherical end, in mm (in),

or for a semi-elliptical end, the internal radius of the meridian of the ellipse at the centre of the opening, in mm (in) (see Note),

t_a = actual thickness of the ring or standpipe, in mm (in),

d_O = external diameter of the ring or standpipe, in mm (in).

The dimensions l_1 and l_2 are shown in Fig. J 2.11.

Chapter J

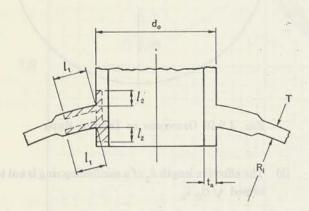
The shape factor K for a dished end having a reinforced opening can be read from Chart J 2.5 using the value obtained from:—

$$\frac{d_o - \frac{A}{T}}{\sqrt{D_o T}} \quad \text{instead of from} \quad \frac{d}{\sqrt{D_o T}}$$

where A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. J 2.11.

The area shown in Fig. J 2.11 is to be calculated as follows:—

- (i) Calculate the sectional area of reinforcement both inside and outside the end plate within the length l_1 .
- (ii) Add to it the full sectional area of that part of the ring or standpipe which projects inside the end plate up to the distance \(l_2 \).
- (iii) Add to it the full sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance \(\bar{l}_2\) and deduct from it the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with 222.



 $l_{\rm t} = \sqrt{2{\sf R}_{\rm i}{\sf T}}$ or 0,5d_o whichever is the lesser $l_{\rm 2}$ shall not exceed $\sqrt{{\sf d}_{\rm o}{\sf t}_{\rm a}}$

FIG. J 2.11 LIMITS OF REINFORCEMENT

If the material of the ring or the reinforcing plates has an allowable stress lower than that of the end plate then the effective cross-section A must be reduced below that calculated in proportion to the difference in the allowable stresses for the materials. As in 211 trial calculation is necessary in order to select the correct curve.

NOTE. For the internal radius, R₁, of the meridian of the ellipse at the centre of the opening (see Fig. J 2.9c):—

$$R_{I} = \frac{\left[a^{4} - x^{2} \left(a^{2} - b^{2}\right)\right]^{\frac{3}{2}}}{a^{4} b}$$

DISHED ENDS RESTRICTED TO CLASS 3 PRESSURE VESSELS ONLY

Minimum Thickness

215 The minimum thickness, T, of a torispherical unstayed end dished from plate and having pressure on the concave or convex side is to be determined by the following formula:—

$$T = \frac{PR_i}{CS}$$

where T, P and R; are as defined in J 110,

C = 25,7 (576) for ends concave to pressure,

C = 16.5 (370) for ends convex to pressure,

S = specified minimum tensile strength of plate, in kg/mm² (ton/in²), which should be not less than 42 kg/mm² (26·7 ton/in²).

The inside radius of curvature, R_i, of the end plate is not to be greater than the external diameter of the cylinder to which it is attached.

The inside knuckle radius, r_i , of the arc joining the cylindrical flange to the spherical surface of the end is not to be less than four times the thickness of the end plate and in no case less than 65 mm (2.5 in).

Ends convex to pressure are not to be used for vessels exceeding 610 mm (24 in) internal diameter.

Where the end is provided with a flanged manhole the thickness of the end, in mm (in), determined by the foregoing formula is to be increased by 3 mm (0·125 in) and the total depth H of the manhole flange, measured from the outer surface of the plate on the minor axis is not to be less than

$$H = \sqrt{T_i W}$$

where H = depth of flange, in mm (in),

T₁ = required thickness of the plate, in mm (in),

W = minor axis of the manhole, in mm (in).

CONICAL ENDS SUBJECT TO INTERNAL PRESSURE

General

216 Conical ends and conical reducing sections as shown in Fig. J 2.12 are to be designed in accordance with the equations given in 217.

Connections between cylindrical shell and conical sections and ends shall preferably be by means of a knuckle transition radius. Typical permitted details are shown in Fig. J 2.12. Alternatively, conical sections and ends may be butt-welded to cylinders without a knuckle radius when the change in angle of slope ψ between the two sections under consideration does not exceed 30°.

Conical ends may be constructed of several ring sections of decreasing thickness as determined by the corresponding decreasing diameter.

Minimum Thickness

217 The minimum thickness, T, of the cylinder, knuckle and conical section at the junction and within the distance L from the junction is to be determined by the following formula:—

$$T = \frac{P D_0 K}{2 f J} + 0.75 mm$$
 (1)

$$\left(T\,=\,\frac{P\;D_{\,\text{O}}\;K}{2\;f\;J}\;+0\!\cdot\!03\,\mathrm{in}\;\right)$$

If the distance of a circumferential seam from the knuckle or junction is not less than L then J is to be taken as 1,0, otherwise J is to be the weld joint factor appropriate to the circumferential seam.

In the event of the thickness T determined by formula (2) being greater than that obtained using formula (1), the greater of the two thicknesses is to apply.

The minimum thickness T of those parts of conical sections not less than a distance L away from the junction with a cylinder or other conical section is to be determined by the following formula:—

$$T = \frac{P D_c}{(2 f J - P)} \left(\frac{1}{\cos \alpha}\right) + 0.75 \text{ mm}$$
 (2)

$$\left(T = \frac{P D_{\text{C}}}{(2 \text{ f J} - P)} \left(\frac{I}{\cos \alpha}\right) + 0.03 \text{ in}\right)$$

where T, P, f and J are as defined in J 110,

D_C = inside diameter, in mm (in), of conical section or end at the position under consideration (see Fig. J 2.12),

D_O = outside diameter, in mm (in), of the conical section or end (see Fig. J 2.12),

r_i = inside radius of transition knuckle, in mm (in), which is to be taken as 0,01 D_C in the case of conical sections without knuckle transition,

 α , α 1, α 2 = angle of slope of conical section (at the point under consideration) to the vessel axis (see Fig. J 2.12),

ψ = difference between angle of slope of two adjoining conical sections (see Fig. J 2.12),

K = a factor, taking into account the stress in the knuckle (see Table J 2.1),

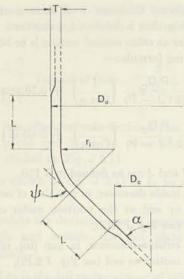
L = distance, in mm (in), from knuckle or junction within which meridional stresses determine the required thickness (see Fig. J 2.12),

$$= 0.5 \sqrt{\frac{D_0 T}{\cos \psi}}$$

The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

TABLE J 2.1 VALUES OF K AS A FUNCTION OF ψ AND r_i/D_O

				V	alues o	f K for	ri/Do	ratios o	f			
ψ	0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,20	0,30	0,40	0,50
10°	0,70	0,65	0,60	0,60	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
20°	1,00	0,90	0,85	0,80	0,70	0,65	0,60	0,55	0,55	0,55	0,55	0,55
30°	1,35	1,20	1,10	1,00	0,90	0,85	0,80	0,70	0,65	0,55	0,55	0,55
45°	2,05	1,85	1,65	1,50	1,30	1,20	1,10	0,95	0,90	0,70	0,55	0,55
60°	3,20	2,85	2,55	2,35	2,00	1,75	1,60	1,40	1,25	1,00	0,70	0,55
75°	6,80	5,85	5,35	4,75	3,85	3,50	3,15	2,70	2,40	1,55	1,00	0,55



(a) Cone/cylinder with knuckle

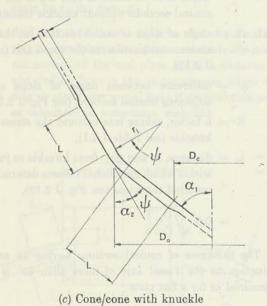
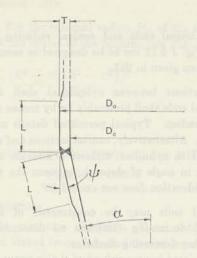
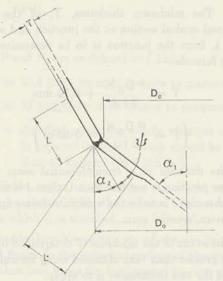


Fig. J 2.12



(b) Cone/cylinder without knuckle



(d) Cone/cone without knuckle

STANDPIPES AND BRANCHES

Minimum Thickness

218 The minimum wall thickness of standpipes and branches is not to be less than that determined by 222 making such additions as may be necessary on account of bending, static loads and vibration.

The wall thickness, however, is not to be less than:— $\mathsf{T} = 0.04 \; \mathsf{D_0} + 2.5 \; \mathrm{mm} \quad \big(\mathsf{T} = 0.04 \; \mathsf{D_0} + 0.1 \; \mathrm{in}\big)$ where T and D_O are as defined in J 110.

In no case need the wall thickness exceed that of the shell.

Where a standpipe or branch is connected by screwing the thickness is to be measured at the root of the thread.

For boiler, superheater or economiser tubes the minimum thickness of the drum or header connection or tube stub is to be calculated as part of the tube in accordance with 222.

HEADERS

Rectangular Section Headers

219 The thickness of flat surfaces of rectangular solid forged headers (exclusive of staggered, sinuous or corrugated headers) is not to be less than:—

$$T + 0.75 \text{ mm} \quad (T + 0.03 \text{ in})$$
 (1)

where T = the greatest basic thickness, in mm (in), derived as follows by the use of Chart J 2.6 which gives ratios of thickness to effective width of header.

Two investigations are necessary to deal with:-

- (i) the stress at the corner of the header,
- (ii) the stress in the ligaments between tube holes or other openings piercing the flat face of the header.

The efficiency J of the ligaments is calculated as in 202 to 205.

Where a header is drilled for several rows of tube holes the lowest calculated efficiency is to be used.

Chart J 2.6 shows values of $\frac{T}{B}$ corresponding to values

of a term K for parameters of $\frac{A}{B}$

- where A = the distance, in mm (in), between the centre line of the openings and the limit of the effective width "B" of the header (where there is more than one row of holes, "A" is the distance to the row showing the lowest efficiency),
 - B = the effective width, in mm (in), of the pierced surface under consideration measured between the supporting sides of the headers, minus one corner radius. This effective width is not to be taken as less than 0,9 of the full distance between the sides.

The corner radius is not to be less than 6.5 mm (0 \cdot 25 in) (see illustration of "A" and "B" on Chart J 2.6).

$$K = \frac{f J}{P}$$

where P and f are as defined in J 110,

J = the lowest ligament efficiency expressed as a fraction.

It will be seen that in case (i) $\frac{A}{B} = 0$ and J = 1.

Where the header surfaces are machined locally at hand holes the total thickness may be reduced by a maximum of 4 mm (0·15 in).

Except for small areas not exceeding 3,25 cm² (0.5 in²) where a reduction of designed thickness up to 50 per cent may be permitted, the thickness derived from use of Chart J 2.6 is to be the minimum. Such minimum is in no case to be less than 7,5 mm (0.3 in) or, where tube holes are drilled, to be less than

$$T = 0.5 \sqrt{d + 6.35 \text{ mm}}$$
 (2)
 $(T = 0.1 \sqrt{d + 0.25 \text{ in}})$

where d = the diameter of the tube hole, in mm (in).

Staggered, Sinuous or Corrugated Headers

220 The scantlings of staggered, sinuous or corrugated headers shall be the subject of special consideration.

Where sufficient experience of previous satisfactory service of similar headers cannot be shown, the suitability of headers is to be proved in accordance with the provisions of J 108.

Header Ends

221 The shape and thickness of ends forged integrally with the bodies of headers are to be the subject of special consideration.

Where sufficient experience of previous satisfactory service of headers with similar ends cannot be shown the suitability of a proposed form of end is to be proved in accordance with the provisions of J 108.

Ends attached by welding are to be designed as follows:—

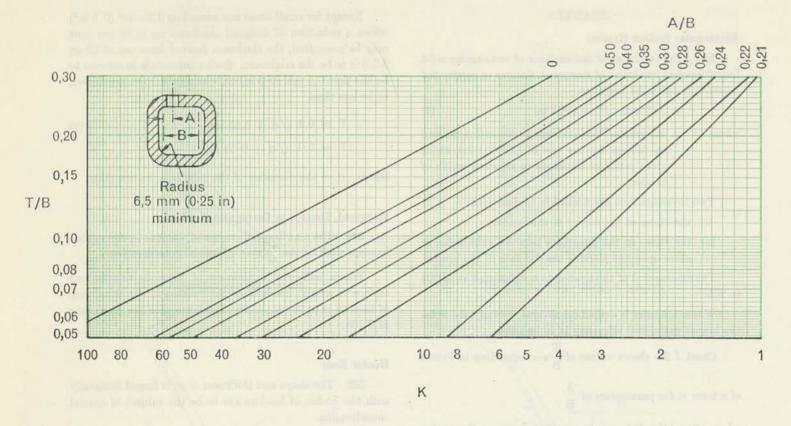
- (a) Dished ends. These are to be in accordance with 209.
- (b) Flat ends. The minimum thickness of flat end plates is to be determined by the following formula:—

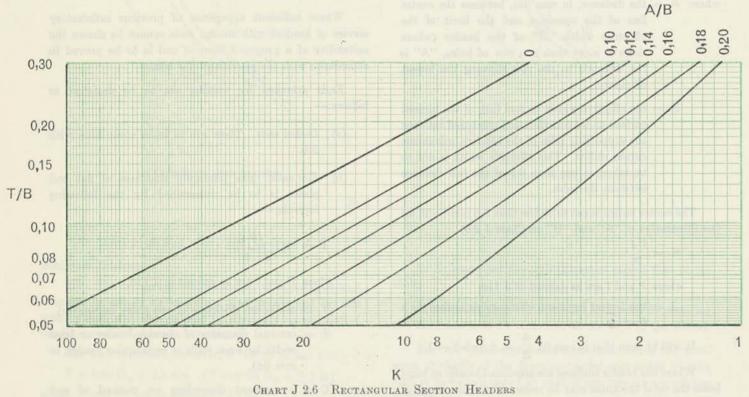
$$T = d_i \sqrt{\frac{PC}{f}}$$

where P and f are as defined in J 110,

T = minimum thickness of end plate, in mm (in),

- d_i = internal diameter of circular header or least width between walls of rectangular header, in mm (in).
- C = a constant depending on method of end attachment (see Fig. J 2.13).





For end plates welded as shown in Fig. J 2.13a

C = 0,19 for circular headers, 0,32 for rectangular headers.

For end plates welded as shown in Figs. J 2.13b and J 2.13c.

C = 0,28 for circular headers,0,40 for rectangular headers.

Where flat end plates are bolted to flanges attached to the ends of headers the flanges and end plates are to be in accordance with recognised pipe flange standards.

BOILER TUBES SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

222 The minimum wall thickness T of tubes subject to internal pressure is to be determined by the following formula:—

$$T = \frac{PD_0}{2f + P}$$

where

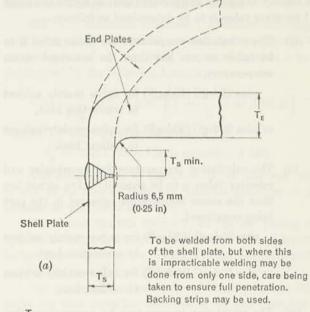
T, P, Do and f are as defined in J 110.

The thickness T is in no case to be less than the minimum shown in Table J 2.2.

It should be noted that T derived from the above formula is the minimum thickness of straight tubes and further provision must be made for minus tolerances where necessary and also in cases where abnormal corrosion or erosion is expected in service. For bending allowances, see 224.

It is recommended that the thickness of tubes determined by the above formula be increased by 0,25 mm (0·01 in) for tubes subject to internal pressure and fitted in cylindrical boilers, and also tubes of low pressure water tube boilers having a design pressure of 17,5 kg/cm² (250 lb/in²) and under with open feed systems.

The minimum thickness of boiler, superheater, reheater and economiser tubes is to be determined by using the design stress appropriate to the mean wall temperature which shall be considered to be the metal temperature. Unless it is otherwise agreed between the manufacturer and



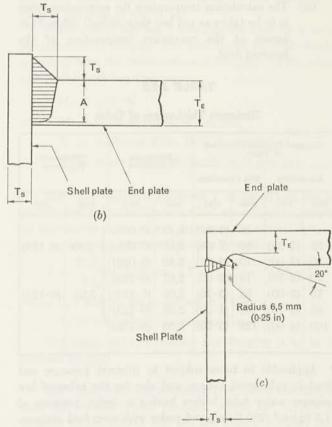


Fig. J 2.13 Typical Methods of Attachment of Header End Closures

Ts = thickness of unpierced shell.

 T_E = thickness of end plate.

 $A = 2 T_S \text{ or } T_E - 1.6 \text{ mm } (T_E - 0.0625 \text{ in}) \text{ whichever}$ is less.

the Society, the metal temperature used to decide the value of f for these tubes is to be determined as follows:—

 (i) The calculation temperature for boiler tubes is to be taken as not less than the saturated steam temperature,

> plus 25degC (45degF) for tubes mainly subject to convection heat,

or plus 50degC (90degF) for tubes mainly subject to radiant heat.

(ii) The calculation temperature for superheater and reheater tubes is to be generally taken as not less than the steam temperature expected in the part being considered,

> plus 35degC (63degF) for tubes mainly subject to convection heat,

or plus 50degC (90degF) for tubes mainly subject to radiant heat.

(iii) The calculation temperature for economiser tubes is to be taken as not less than 35degC (63degF) in excess of the maximum temperature of the internal fluid.

TABLE J 2.2

Minimum Thicknesses of Tubes

Nominal Outside Diameter of Tube				imum	*Minimum Thickness		
Exceeding		Not e	Not exceeding		Thickness		KIIVSS
mm	(in)	mm	(in)	mm	(in)	mm	(in)
-		38	(1.50)	1,75	(0.069))	
38	(1.50)	50	(2.00)	2,16	(0.085)	2,95	(0.116)
50	(2.00)	70	(2.75)	2,40	(0.095)		
70	$(2 \cdot 75)$	75	(3.00)	2,67	(0.105)	1	
75	(3.00)	95	(3.75)	3,05	(0.120)	3,28	(0.129)
95	(3.75)	100	(4.00)	3,28	(0.129)		
100	(4.00)	125	(5.00)	3,50	(0.138)	1.00	

* Applicable to tubes subject to internal pressure and fitted in cylindrical boilers, and also for the tubes of low pressure water tube boilers having a design pressure of 17,5 kg/cm² (250 lb/in²) and under with open feed systems.

223 The minimum thickness of downcomer tubes and pipes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the Rules for steam pipes.

Tube Bending

224 Where boiler, superheater, reheater and economiser tubes are bent, the resulting thickness of the tubes at the thinnest part is not to be less than that required for straight tubes, unless it can be demonstrated that the method of forming the bend results in no decrease in strength at the bend as compared with the straight tube. The manufacturer is to demonstrate in connection with any new method of tube bending that this condition is satisfied.

Tube bending and subsequent heat treatment, where necessary, is to be so carried out as to ensure that residual stresses do not adversely affect the strength of the tube for the design purpose intended.

Cross-references

225 For details of manholes, sight holes and doors, see J 301 to J 307.

For details of tube holes and fitting of tubes, see J 313.

Tube Plates of Vertical Boilers

226 Where vertical boilers have a nest or nests of horizontal tubes so that there is direct tension on the tube plates due to the vertical load on the boiler ends or to their acting as horizontal ties across the shell, the thickness of the tube plates in way of the outer rows of tubes is to be determined by the following formula:—

$$T = \frac{2 P D}{J R_{20}} + 0.75 \text{ mm } \left(T = \frac{2 P D}{J R_{20}} + 0.03 \text{ in}\right)$$

where T and P are as defined in J 110,

D = twice the radial distance of the centre of the outer row of tube holes from the axis of the shell, in mm (in),

R₂₀ = specified minimum tensile strength of tube plate, in kg/cm² (lb/in²),

J = efficiency of ligaments between tube holes in the outer vertical rows (expressed as a fraction),

i.e.
$$J = \frac{(p-d)}{p}$$

where p = vertical pitch of tubes, in mm (in),

d = diameter of tube holes, in mm (in).

Each alternate tube in the outer vertical rows of tubes is to be a stay tube. Further, the arrangement of stay tubes in the nests is to be such that the thickness of the tube plates meet the requirements of 243 and 244.

Where the vertical height of the tube plates between the top and bottom shelves exceeds 0,65 times the internal diameter of the boiler, the staying of the tube plates, and the scantlings of the tube plates and shell plates to which the sides of the tube plates are connected, will require to be specially considered. It is recommended, however, that for this type of boiler, the vertical height of the tube plates between the top and bottom shelves should not exceed 1,25 times the internal diameter of the boiler.

Horizontal Shelves of Tube Plates Forming Part of the Shell

227 For vertical boilers of the type referred to in 226, in order to withstand the vertical load due to pressure on the boiler ends the horizontal shelves of the tube plates are to be supported by gussets in accordance with the following formula:—

$$C = \frac{A D_i P}{T}$$

where A = maximum horizontal dimension of the shelf from the inside of the shell plate to the outside of the tube plate, in mm (in),

D_i = inside diameter of the boiler, in mm (in),

P = design pressure, in kg/cm² (lb/in²),

T = thickness of the tube plate, in mm (in).

For the combustion chamber tube plate the minimum number of gussets shall be:—

1 gusset where C exceeds 261 000 (146 000),

2 gussets where C exceeds 357 000 (200 000),

3 gussets where C exceeds 428 000 (240 000).

For the smoke box tube plate the minimum number of gussets shall be:—

1 gusset where C exceeds 261 000 (146 000),

2 gussets where C exceeds 482 000 (270 000).

The shell plates to which the sides of the tube plates are connected are not to be less than 1,6 mm (0·0625 in) thicker than is required by the formula applicable to shell plates with continuous circularity; and where gussets or other stays are not fitted to the shelves, the strength of the parts of the circumferential seams at the top and bottom of these plates from the outside of one tube plate to the outside of the other, is to be sufficient to withstand the whole load on the boiler end with a factor of safety of not less than 4,5 related to R_{20} (R_{20} being the specified minimum tensile strength of the shell plates, in kg/cm² (lb/in²)).

Dished and Flanged Ends for Vertical Boilers

228 The minimum thickness T of dished and flanged ends for vertical boilers which are subject to pressure on the concave side and are supported by central uptakes is to be determined by the following formula:—

$$T = \frac{P R_1}{2 f_2} + 0.75 \text{ mm } \left(T = \frac{P R_1}{2 f_2} + 0.03 \text{ in}\right)$$

where T, P and R; are as defined in J 110,

f₂ = 0,65 f where f is as defined in J 110.

The inside radius of curvature R_i of the end plate is not to be greater than the external diameter of the cylinder to which it is attached.

The inside knuckle radius r_i of the arc joining the cylindrical flange to the spherical surface of the end is not to be less than four times the thickness of the end plate and in no case less than 65 mm (2.5 in).

The inside radius of curvature of flange to uptake is not to be less than twice the thickness of the end plate and in no case less than 25 mm (1 in).

If the dished end has a manhole the opening is to be strengthened by flanging. The total depth, H, of the flange, measured from the outer surface of the plate on the minor axis shall be not less than:—

$$H = \sqrt{T W}$$

where H = depth of flange, in mm (in),

T = thickness of the plate, in mm (in),

W = minor axis of the manhole, in mm (in).

229 The minimum thickness T of dished and flanged ends for vertical boiler furnaces which are subject to pressure on the convex side and are supported by central uptakes is to be determined by the following formula:—

$$T = \frac{P R_0}{2 f_3} + 0.75 \text{ mm } \left(T = \frac{P R_0}{2^8 f_3} + 0.03 \text{ in}\right)$$

where T, P and Ro are as defined in J 110,

 $f_3 = 0.5 f$ where f is as defined in J 110.

The inside radii of dishing and flanging is to be as required by 228.

230 The minimum thickness T of dished and flanged ends for vertical boiler furnaces, which are subject to pressure on the convex side and are without support from stays of any kind, is to be determined by the following formula but is in no case to be less than the thickness of the firebox:—

$$\mathsf{T} = \frac{\mathsf{C} \, \mathsf{P} \, \mathsf{R}_{\mathsf{O}}}{675} + 0.75 \, \mathsf{mm} \qquad \quad \left(\mathsf{T} \, = \frac{\mathsf{C} \, \mathsf{P} \, \mathsf{R}_{\mathsf{O}}}{9600} + 0.03 \, \mathsf{in}\right)$$

where T and P are as defined in J 110,

 R_0 = outside radius of the crown plate, in mm (in). In no case is $\frac{R_0}{T}$ to exceed 88.

 $C = \frac{2 x}{x+f}$ which must not be taken as less than 0,85 where x and f are as defined in 232.

The inside radius of curvature, R_i, of the end plate is not to be greater than the external diameter of the cylinder to which it is attached.

The inside knuckle radius r_i of the arc joining the cylindrical flange to the spherical surface of the end is not to be less than four times the thickness of the end plate and in no case less than 65 mm (2.5 in).

CYLINDRICAL FURNACES SUBJECT TO EXTERNAL PRESSURE

Note. Furnaces, plain or corrugated, are not to exceed 22,5 mm (0.875 in) in thickness.

Corrugated Furnaces

231 The minimum thickness T of corrugated furnaces is to be determined by the following formula:—

$$T = \frac{PD_0}{C} + 0.75 \text{ mm}$$
 $\left(T = \frac{PD_0}{C} + 0.03 \text{ in}\right)$

where P is as defined in J 110,

Do = external diameter of the furnace measured at the bottom of the corrugations, in mm (in),

T = thickness of the furnace plate measured at the bottom of the corrugations, in mm (in),

C = 1080 (15 350) for Fox, Morison and Deighton corrugations,

= 1150 (16 300) for Suspension Bulb corrugations,

Plain Furnaces, Flue Sections and Combustion Chamber Bottoms

232 The minimum thickness T of plain furnaces or furnaces strengthened by the Adamson or other joints, of flue sections and of the cylindrical bottoms of combustion chambers is to be determined by the following formulæ, the greater of the two thicknesses obtained being taken:—

$$T = \sqrt{\frac{P D_o (L + 610)}{104400}} + 0.75 \text{ mm}$$
 (1)

$$\left(T = \sqrt{\frac{PD_0 (L + 24)}{1.5 \times 10^6}} + 0.03 \text{ in}\right)$$

$$T = \frac{C P D_0}{1120} + \frac{L}{320} + 0.75 \,\text{mm} \tag{2}$$

$$\left(T = \frac{CPD_0}{16000} + \frac{L}{320} + 0.03 \text{ in}\right)$$

where T and P are as defined in J 110,

D_O = external diameter of the furnace, flue or combustion chamber, in mm (in),

L = length of section between the centres of points of substantial support, in mm (in),

$$C = \frac{2x}{x + f}$$

X = 0,2% proof stress, in kg/cm² (lb/in²), at a temperature 90degC (162degF) above the saturated steam temperature corresponding to the design pressure for 42-52 kg/mm² (26·7-33·0 ton/in²) carbon steel Category II material as shown in Chapter Q, Table Q 3.4.

f = minimum specified 0,2% proof stress, in kg/cm² (lb/in²) at temperature 90degC (162 degF) above the saturated steam temperature corresponding to the design pressure for the steel actually used.

Plain Furnaces of Vertical Boilers

233 The thickness of plain furnaces not exceeding 1700 mm (5 ft 6 in) in external diameter is to be determined by the formulæ given in 232; the greater of the two thicknesses being taken:—

where D = external diameter of the furnace, in mm (in).

Where the furnace is tapered, the diameter to be taken for calculation purposes is to be the mean of that at the top and that at the bottom where it meets the substantial support from flange, ring or row of stays,

L = effective length, in mm (in), of the furnace between the points of substantial support as indicated in Fig. J 2.14.

In no case, however, is the thickness to be more than 22,5 mm (0.875 in). For furnaces under 760 mm (2 ft 6 in) in external diameter the thickness is not to be less than 8 mm (0.3125 in), and for furnaces 760 mm (2 ft 6 in) in external diameter and over, the thickness is not to be less than 9,5 mm (0.375 in). Furnaces exceeding 1700 mm (5 ft 6 in) in external diameter shall be the subject of special consideration.

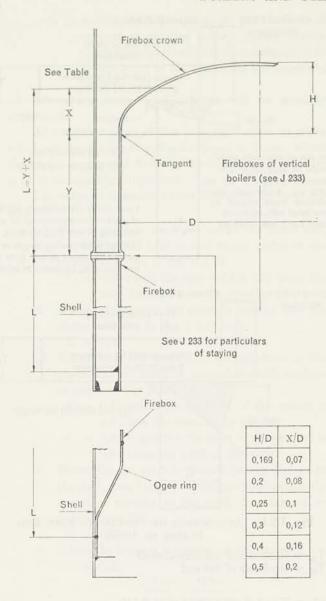


Fig. J 2.14 Effective Length "L" for use in J 233

A circumferential row of stays connecting the furnace to the shell shall be considered to provide substantial support to the furnace, provided:—

- (a) the diameter of the stay be not less than 22,5 mm (0.875 in) or twice the thickness of the furnace, whichever is the greater. In the case of screwed stays the diameter is to be measured over the threads.
- (b) the pitch of the stays at the furnace does not exceed 14 times the thickness of the furnace.

Hemispherical Furnaces

234 The minimum thickness T of unsupported hemispherical furnaces subject to pressure on the convex surface is to be determined by the following formula:—

$$T = \frac{C P R_0}{620} + 0.75 \text{ mm}$$
 $\left(T = \frac{C P R_0}{8800} + 0.03 \text{ in}\right)$

where T and P are as defined in J 110,

R_O = outer radius of curvature of the furnace, in mm (in),

 $C = \frac{2x}{x + f}$ which must not be taken as less than 0,85.

x and f are as defined in 232.

In no case, however, is T to exceed 22,5 mm (0·875 in) and the ratio $\frac{R_o}{T - 0.75} \left(\frac{R_o}{T - 0.03} \right)$ British to exceed 100.

Ogee Rings

235 The minimum thickness T of the ogee ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains the whole vertical load on the furnace is to be determined by the following formula:—

$$T = \sqrt{\frac{P D_i (D_i - D_o)}{10110} + 0.75 \text{ mm}}$$

$$\left(T = \sqrt{\frac{P D_i (D_i - D_o)}{144000} + 0.03 \text{ in}}\right)$$

where T and P are as defined in J 110,

D_i = inside diameter of boiler shell, in mm (in),

D_O = outside diameter of the lower part of the furnace where it joins the ogee ring, in mm (in).

Uptakes of Vertical Boilers

236 The minimum thickness T of internal uptakes of vertical boilers is to be determined by the following formulæ, the greater of the two thicknesses obtained being taken:—

$$T = \sqrt{\frac{P D_0 (L + 610)}{104 400}} + 4 mm \tag{1}$$

$$\left(T = \sqrt{\frac{P D_0 (L + 24)}{1.5 \times 10^6} + 0.156 \text{ in}}\right)$$

$$T = \frac{P D_0}{1120} + \frac{L}{320} + 4 \text{ mm}$$

$$\left(T = \frac{P D_0}{16000} + \frac{L}{320} + 0.156 \text{ in}\right)$$
(2)

where T and P are as defined in J 110,

Do = external diameter of uptake, in mm (in),

L = length of uptake between the centres of points of substantial support, in mm (in).

Cross Tubes

237 Cross tubes shall not exceed 300 mm (12 in) internal diameter. The minimum thickness T is to be determined by the following formula but is in no case to be less than 9.5 mm (0·375 in).

$$T = \frac{P D_i}{450} + 6.5 \text{ mm } \left(T = \frac{P D_i}{6400} + 0.25 \text{ in}\right)$$

where T and P are as defined in J 110,

D_i = internal diameter of cross tube, in mm (in).

Stayed Flat Surfaces

238 Where flat end plates are flanged for connection to the shell, the inside radius of flanging is not to be less than 1,75 times the thickness of the plate, with a minimum of 38 mm (1.5 in).

Where combustion chamber or firebox plates are flanged for connection to the wrapper plate, the inside radius of flanging is to be equal to the thickness of the plate, with a minimum of 25 mm (1 in).

Where unflanged flat plates are connected to the shell by welding, the methods of attachment are to be as shown in Fig. J 2.15. Similar forms of attachment may be used where unflanged combustion chamber or fire box plates are connected to the wrapper plate by welding.

239 Where the flange curvature is a point of support, this is to be taken at the commencement of curvature, or at a line 3,5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange.

Where a flat plate is welded directly to a shell or wrapper plate, the point of support is to be taken at the inside of the shell or wrapper plate.

240 The thickness T of those portions of flat plates supported by stays is to be determined by the following formula:—

$$T = Cd \sqrt{\frac{P}{f_1}} + 0.75 \text{ mm } \left(T = Cd \sqrt{\frac{P}{f_1}} + 0.03 \text{ in}\right)$$

9,5 mm (0-375 in) 6,5 mm (0-25 in) minimum + 3 mm (0-125 in) maximum 1,6 mm (0-0625 in) minimum 3 mm (0-125 in) maximum See Note 10°-20° r = 9,5 mm - 5 mm The use of minimum angle (0.375 in - 0.197 in) should be associated with maximum radius r of 9,5 mm (0.375 in). Conversely, the Note: maximum angle should be 5 mm (0·197 in) minimum leg length associated with minimum of weld for end plates up to and TE radius r of 5 mm (0.197 in) including 20 mm (0-75 in) thick. 6,5 mm (0.25 in) minimum leg length of weld for end plates above 20 mm (0-75 in) up to and including 32 mm (1-25 in) thick

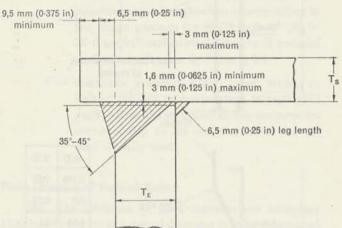


Fig. J 2.15 Attachment of Unflanged Flat End Plates to Shell

 T_S = thickness of cylindrical shell T_F = thickness of flat end

where T and P are as defined in J 110,

f, = 0,85 f where f is as defined in J 110,

 $d = \sqrt{A^2 + B^2}$ where the stays are regularly pitched.

A being the horizontal pitch of the stays and B the vertical pitch of the stays.

Where the stays are irregularly pitched, then

d = diameter of the largest circle which can be drawn through three points of support without enclosing another point of support. Only two points of support may lie on one side of any diameter of the circle.

Where a flange is taken as a point of support, the circumference of the circle is to be tangent to the line of curvature (see 239).

C = a constant, depending on the method of support as detailed below. Where various forms of support are used the constant C is to be the mean of the values for the respective methods adopted.

Alternative methods of support will be specially considered.

All constants given in this paragraph relate to plates which are stress relieved and not exposed to flame. Where the plates are exposed to flame the thickness of the plate is to be increased by 10 per cent.

The value of C in the above formula is to be as follows:—

- (1) Where stays are screwed through the plates and, in addition, are fillet welded to the plates on the outside as shown in Fig. J 2.16:—
 - C = 0,39 where the fillet weld is 0,35 times the stay diameter over the thread.
- (2) Where plain stays are strength welded into the plates as shown in Fig. J 2.17:—
- (3) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in Fig. J 2.18:—
 - C = 0,35 where the diameter of the washer is 3,5 times the diameter of the stay.
 - C = 0,33 where the diameter of the washer is 0,67 times the pitch of the stays.
- (4) Where the flat plate is flanged for attachment to the shell, flue, furnace or wrapper or alternatively is welded directly to the shell, flue, furnace or wrapper (see 239):—

C = 0.33.

C = 0.39.

(5) Where the support is a gusset or link stay:—
C = 0,39.

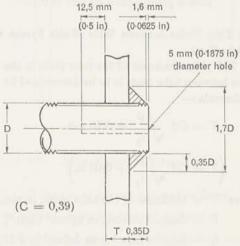


Fig. J 2.16 Attachment of Firebox and Combustion Chamber Stays

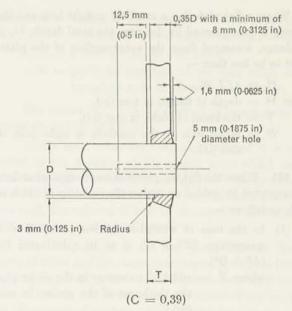


Fig. J 2.17 Attachment of Firebox, Combustion Chamber Stays and Bar Stays

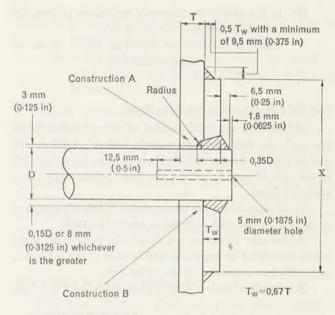


Fig. J 2.18 Attachment of Bar Stays

Method of construction "A" or "B" may be used except where T_W is less than 0,35D when the form of construction shown in "A" is to be used.

Diameter of washer "X"	Value of constant C
X = 3,5D	0,35
X = 0,67 pitch of stays	0,33

Chapter J

Where a flat plate has a manhole or sight hole and the opening is strengthened by flanging, the total depth, H, of the flange, measured from the outer surface of the plate, is not to be less than:—

$$H = \sqrt{TW}$$

where H = depth of flange, in mm (in),

T = thickness of plate, in mm (in),

W = minor axis of the manhole or sight hole, in mm (in).

241 Where the flat top plates of combustion chambers are supported by welded-on girders the equation in 240 is to apply as follows:—

(1) In the case of welded-on girders provided with waterways, $(X^2 + Y^2)$ is to be substituted for $(A^2 + B^2)$.

where X = width of waterway in the girder plus the thickness of the girder, in mm (in),

Y = pitch of girders, in mm (in):-

C = 0.42.

(2) In the case of continuously welded-on girders, D^2 is to be substituted for $(A^2 + B^2)$,

where D = distance between inside faces of girders, in mm (in):—
C = 0.51.

Flat Tube Plates within the Tube Nests

242 Where the total number of tubes is arranged in one nest, the area of which exceeds 0,65 m² (7 ft²) in the case of directly fired multitubular boilers, and 2 m² (21 ft²) in the case of multitubular waste heat boilers, stay tubes are to be fitted.

In all cases where the total number of tubes is arranged in more than one nest, stay tubes are to be fitted.

Where stay tubes are not fitted, the ends of all tubes are to be welded or expanded and beaded at the inlet end, and welded or expanded at the outlet end.

For details of seal welding of plain tubes, see Fig. J 2.19.

3 mm (0·125 in) minimum
5 mm (0·1875 in) maximum

FIG. J 2.19 DETAIL OF SEAL-WELD FOR PLAIN TUBE

243 Where stay tubes are required to be fitted the thickness of those parts of the tube plates within the tube nests is to be determined by the following formula:—

$$T=CM~\sqrt{\frac{P}{f_4}}+0.75~\mathrm{mm}$$

$$\left(T = CM \sqrt{\frac{P}{f_5}} + 0.03 \text{ in}\right)$$

where T = thickness of tube plate, in mm (in),

P = design pressure, in kg/cm² (lb/in²),

 $f_5 = 0.85 f$ where f is as defined in J 110,

M = mean pitch, in mm (in), of the stay tubes supporting any positions of the plate (being the sum of the four sides of any quadrilateral divided by 4),

C = 0,42 for plates not exposed to flame with stay tubes secured as shown in Fig. J 2.20,

C = 0,46 for plates exposed to flame.

Where the area of the tube nest does not exceed 0,65 m² (7 ft²) in the case of direct fired boilers or 2 m² (21 ft²) in the case of waste heat boilers, and stay tubes are not fitted, the thickness of the tube plates is to be determined by the above formula:—

where M = four times the mean pitch, in mm (in), of the plain tubes in the nest,

C = 0,45 for plates not exposed to flame,

C = 0,49 for plates exposed to flame.

The thickness T of any tube plate in the tube area is not to be less than:—

- (a) 12,5 mm (0.5 in) where the diameter of the tube hole does not exceed 50 mm (2 in) and
- (b) 14 mm (0.5625 in) where the diameter of the tube hole is greater than 50 mm (2 in).

Flat Tube Plates between Wide Water Spaces and around Tube Nests

244 The thickness of the tube plate in the wide water space between tube nests is to be determined by the following formula:—

$$T = Cd \sqrt{\frac{P}{f_s}} + 0.75 \text{ mm}$$

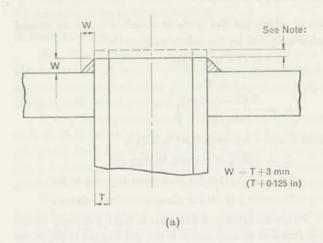
$$\left(T = Cd \sqrt{\frac{P}{f_5}} + 0.03 in\right)$$

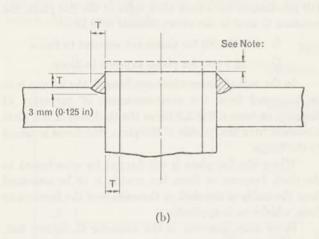
where T = thickness of the tube plate, in mm (in),

P = design pressure, in kg/cm² (lb/in²),

 $f_s = 0.85$ f where f is as defined in J 110,

$$d = \sqrt{A^2 + B^2}$$





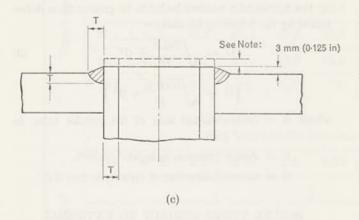


Fig. J 2.20 Attachment of Stay Tubes

C = 0,42 if the plates are not exposed to flame

C = 0,46 if the plates are exposed to flame

Note. The ends of the tubes are to be dressed flush with the welds when exposed to flame or comparatively high temperature. When not exposed, the ends of the tubes may extend a maximum of 9.5 mm (0.375 in) beyond the weld,

where A = width, in mm (in), of the wide water space between the tube nests (measured from the centre line of the stay tubes),

B = pitch, in mm (in), of the stay tubes in the boundary rows of the wide water space.

The values of C and the method of securing the stay tubes are as indicated in 243.

Where stay tubes are irregularly pitched d is to be taken as the diameter of the largest circle which can be drawn through any three points of support without enclosing another point of support. Where various forms of support are used, the value of C is to be the mean of the values for the respective methods adopted.

For the portions of the end plates between the top rows of tubes and the steam space stays, the above formula is to apply, B being taken as the distance between the centre line of the top row of tubes and the centre of the bar stays or other point of support, and A being taken as:—

$$\frac{A_1 + A_2}{2}$$

where A₁ is the horizontal distance between the centres of bar stays or other method of support, and

> A₂ is the horizontal distance between the centre of one stay tube and the centre of the next stay tube in the top boundary row.

Where no stay tubes are fitted A₂ is to be taken as equal to four times the horizontal pitch of the plain tubes.

Where no stay tubes are fitted the support afforded by the plain tubes is not to be taken to extend beyond the line enclosing the outer surfaces of the tubes except that, between the outside of the wing row of tubes and the attachment of the end plate to shell, there may be an unsupported width equal to the flat plate margin as given by 248, formula (1).

Flat Crowns of Vertical Boilers

245 The minimum thickness of flat crown plates of vertical boilers is to be determined by 240; d and C being defined as follows:—

(a) Where the crown is supported by an uptake only,

d = diameter, in mm (in), of the largest circle which can be drawn between the connections to the shell or firebox and uptake (see 238 and 239),

C = 0,47 if the plates are not exposed to flame,

C = 0.51 if the plates are exposed to flame.

Chapter J

(b) Where bar stays are fitted in accordance with 240,

d = diameter, in mm (in), of the largest circle which can be drawn through three points of support without enclosing another point of support,

C = the mean of the values for the respective points of support through which the circle passes.

Combustion Chamber Tube Plates under Compression

246 The thickness of combustion chamber tube plates under compression, due to the pressure on the top plate, based on a compressive stress not exceeding 980 kg/cm² (14 000 lb/in²) is to be determined by the following formula:—

$$T = \frac{P W p}{1970 (p-d)} \left(T = \frac{P W p}{28000 (p-d)}\right)$$

where T and P are as defined in J 110,

W = width of the combustion chamber, in mm (in), measured inside from tube plate to back chamber plate,

p = pitch of tubes, in mm (in), measured horizontally where tubes are chain pitched, or diagonally where the tubes are staggered pitched and the diagonal pitch is less than the horizontal pitch,

d = internal diameter of the plain tubes, in mm (in).

Girders for Combustion Chamber Top Plates

247 The proportions of steel plate girders supporting the tops of combustion chambers is to be determined by the following formula:—

$$T = \frac{3.2 P l^2 p}{d^2 R_{20}}$$

where T and P are as defined in J 110,

d = depth of girder, in mm (in),

length of girder, in mm (in), measured inside from tube plate to back chamber plate,

p = distance apart of the girders, in mm (in),

R₂₀ = specified minimum tensile strength of the girder plate, in kg/cm² (lb/in²).

The above formula is applicable to plate girders welded continuously to the top combustion chamber plate by means of a full penetration weld.

Flat Plate Margins

248 The width of margin, b, of a flat plate which may be regarded as being supported by the shell, furnaces or flues to which the flat plate is attached is not to exceed that determined by the following formula:—

$$b = \frac{C (T-0.75 \text{ mm})}{\sqrt{P}}$$

$$\left(b = \frac{C (T-0.03 \text{ in})}{\sqrt{P}}\right)$$
(1)

where T and Pare as defined in J 110,

b = width of margin, in mm (in),

C = 31,3 (118) for plates not exposed to flame,

C = 29,2 (110) for plates exposed to flame.

Where an unflanged flat plate is welded directly to the shell, furnaces or flues and it is not practicable to effect the full penetration weld from both sides of the flat plate, the constant C used in the above formula is to be:—

C = 23,9 (90) for plates not exposed to flame,

C = 22,5 (85) for plates exposed to flame.

In the case of plates which are flanged, the margin is to be measured from the commencement of curvature of flanging, or from a line 3,5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange.

Where the flat plate is not flanged for attachment to the shell, furnaces or flues, the margin is to be measured from the inside of the shell or the outside of the furnaces or flues, whichever is applicable.

In no case, however, is the diameter D, in mm (in), of the circle forming the boundary of the margin supported by the uptake of a vertical boiler to be greater than determined by the following formula:—

$$D = \sqrt{\frac{352 \text{ A}}{P} + d^2}$$

$$\left(D = \sqrt{\frac{5000 \text{ A}}{P} + d^2}\right)$$
(2)

where A = cross-sectional area of the uptake tube, in mm^2 (in²),

P = design pressure, in kg/cm² (lb/in²),

d = external diameter of uptake, in mm (in).

BOILER TUBES SUBJECT TO EXTERNAL PRESSURE INCLUDING PLAIN AND STAY SMOKE TUBES FOR CYLINDRICAL BOILERS

Stay Tubes

249 Each stay tube is to be designed to carry its due proportion of the load on the plates which it supports. No stay tube is to be less than 5 mm (0.1875 in) thick at its thinnest part.

Stay tubes may be attached to the tube plates either by screwing or by metal arc welding.

Screwed Stay Tubes

250 The maximum stress in a screwed stay tube is not to exceed 527 kg/cm² (7500 lb/in²) based on the net sectional area at the bottom of the thread or in the body of the stay tube, whichever is less.

If stay tubes are increased in thickness at the screwed ends so that the thickness at the bottom of the thread is practically the same as in the body of the tube, the thickening is to be attained by upsetting and not by any welding process, and the tubes are to be annealed after the upsetting.

Where stay tubes are screwed into the tube plates they are to be screwed with a continuous thread not finer than 11 threads per 25,4 mm (1 in) at both ends and are to be expanded into the tube plates by roller expander and, if desired, may be seal welded.

Nuts are not to be fitted to stay tubes at the combustion chamber end.

Welded-in Stay Tubes

251 The thickness of stay tubes welded to tube plates is to be such that the maximum stress on the thinnest part of the tube does not exceed 705 kg/cm² (10 000 lb/in²).

Stay tubes are to be expanded into the tube plate in addition to welding. Typical examples of welded stay tube attachments are shown in Fig. J 2.20.

Stay tubes may be welded into the boiler after stress relief, provided they are not adjacent in the same tube nest.

Plain Tubes

252 The thickness of plain tubes is to be in accordance with Table J 2.3 for the appropriate outside diameter and design pressure.

TABLE J 2.3
Thickness of Plain Tubes

	b a li inte				Outside	diamete	r in mm					Thickness
	38	44,5	51	57	63,5	70	76	82,5	89	95	102	mm
										27,4	25,7	5,89
m 2							fana	26,7	24,6	23,2	21,8	5,38
Design pressure kg/cm²			4421		a malaj		24,6	22,5	21,1	19,7	18,3	4,88
sure				28,1	25,3	23,2	21,1	19,7	18,3	16,9	16,2	4,47
pres		29,9	26,0	23,2	21,1	19,3	17,6	16,2	15,1	14,0	13,0	4,06
esign	27,1	23,2	21,1	18,3	16,2	15,1	13,4	12,6	11,6	10,5	9,8	3,66
O	20,7	17,2	15,1	13,4	12,3	11,2	9,8	9,1	8,4	7,7	7,0	3,25
	15,1	12,6	10,9	9,8	8,8	7,7	42 01					2,95
	agy ta			(Outside o	liameter	in inche	8		well e	y have	Thickness
	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3 · 25	3.5	3.75	4.0	Inches
	10000				72000							
2						1101				390	365	0.232
lb/in²					Total V	1401		380	350	390	365	0.232
ssure lb/in ²						044	350	380	350		The state of the s	
r pressure lb/in²				400	360	330	350 300			330	310	0.212
esign pressure lb/in²		425	370	400	360	330		320	300	330 280	310	0·212 0·192
Design pressure lb/in²	385	425	370				300	320	300	330 280 240	310 260 230	0·212 0·192 0·176
Design pressure lb/in²	385			330	300	275	300	320 280 230	300 260 215	330 280 240 200	310 260 230 185	0·212 0·192 0·176 0·160

Plain tubes may be seal welded at both ends, seal welded at the inlet end and expanded at the outlet end, or expanded at both ends.

Where plain tubes are seal welded, the weld detail is to be as shown in Fig. J 2.19 and the tubes are to be expanded into the tube plates in addition to welding.

Where plain tubes are expanded only, the process is to be carried out with roller expanders, and the expanded portion of the tube is to be parallel through the full thickness of the tube plate. In addition to expanding, tubes may be bell-mouthed or beaded at the inlet end.

Where the total number of tubes is arranged in one nest and no stay tubes are fitted (see 242), the ends of all tubes are to be welded or expanded and beaded at the inlet end, and welded or expanded at the outlet end.

Pitch of Tubes

253 The spacing of tube holes is to be such that the minimum width, in mm (in), of any ligament between the tube holes is not less than:—

0.125 d + 12.5 mm (0.125 d + 0.5 in)

where d = diameter of the tube hole, in mm (in).

Combustion Chambers and Longitudinal Bar Stays

254 The permissible stress in combustion chamber and other similar bar stays, calculated on the minimum sectional area, is not to exceed 633 kg/cm² (9000 lb/in²). The diameter of any stay is not to be less than 19 mm (0.75 in).

255 The permissible stress in longitudinal stays, calculated on the minimum cross-sectional area, is not to exceed minimum specified tensile strength in kg/cm² (lb/in²)

5.3

In no case is the diameter of the stay at any section to be less than 25 mm (1 in).

Loads on Stay Tubes and Bar Stays

256 Stay tubes and bar stays are to be designed to carry the whole load due to the pressure on the area to be supported.

For a stay tube or bar stay, the net area to be supported is to be the area, in mm² (in²), enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support, less the area of any tubes or stays embraced. In the case of a stay tube or bar stay in the boundary rows the support afforded by the flat plate margin, where applicable, should be taken into account.

Where there are no stay tubes in the tube nest, the area to be supported by a bar stay is to extend to the tangential boundary of the tube nest.

Section 3

CONSTRUCTION

Access Arrangements

301 In watertube boilers, manholes are to be provided in all drums of sufficient size to permit access for internal examination and cleaning and for fitting and expanding the tubes. In the case of headers for water walls, superheaters or economisers and of drums which are too small to permit entry, sight holes or mudholes sufficiently large and numerous for these purposes are to be provided.

302 Cylindrical boilers are to be provided, where possible, with means for ingress to permit examination and cleaning of the inner surfaces of plates and tubes exposed to flame. Where the boilers are too small to permit this there are to be sight holes and mudholes sufficiently large and numerous to permit the inside to be satisfactorily cleaned.

303 Where the cross tubes of vertical boilers are large there is to be a sight hole in the shell opposite to one end of each tube sufficiently large to permit the tube to be examined and cleaned. These sight holes are to be in positions accessible for that purpose.

304 Unfired pressure vessels are to be so made that the internal surfaces may be examined and, wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

305 Manholes in cylindrical shells are to have their shorter axes arranged longitudinally, and are to be located clear of the welded joints in the shell.

306. Doors for manholes, mudholes and sight holes are to be formed from steel plate or of other approved construction and all jointing surfaces are to be machined.

The doors are to be of the internal type and are to be provided with spigots which have a clearance of not more than 1,5 mm (0.0625 in) all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm (0.125 in).

307 Doors for openings not larger than 230 mm× 180 mm (9 in×7 in) need only be fitted with one stud which may be forged integral with the door. Larger doors are to be provided with two studs screwed through the door and fitted with nuts on the inside or alternatively, bolts may be used screwed through the door with the heads inside; other methods of attachment may be accepted provided details are submitted for consideration.

The crossbars or dogs are to be of steel.

For smaller circular openings in headers and similar fittings an approved type of plug may be used.

Torispherical and Semi-Ellipsoidal Ends

308 For typical acceptable methods of attaching dished ends to cylindrical shells and for limitations of different types, see Fig. J 3.1.

Types (d) and (e) are to be made a tight fit in the cylindrical shell.

Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate (see J 510).

The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material (see J 209).

Hemispherical Ends

309 Where hemispherical ends are butt welded to cylindrical shells the thickness of the shell is to be reduced by taper to that of the end and the centre of the hemisphere is to be so located that the entire tapered portion of the shell and the butt weld are within the hemisphere (see Fig. J 3.2).

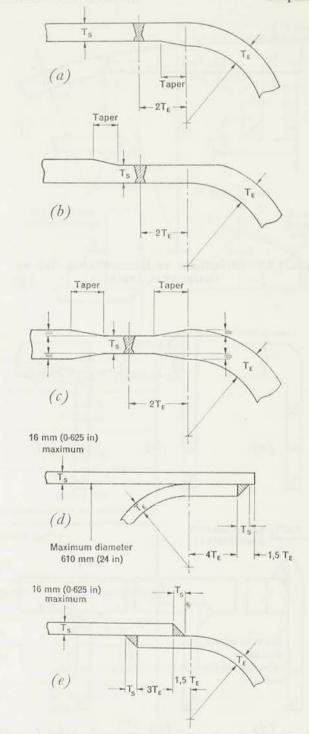
If the hemispherical end is provided with a parallel portion the thickness of this portion is to be not less than that of a seamless or welded shell, whichever is applicable, of the same diameter and material.

Flat End Plates

310 For typical acceptable methods of attaching flat ends to cylindrical and rectangular headers, and to small cylindrical shells; also for the application of the different types, see Fig. J 3.3.

The scantlings of flat end plates for circular and rectangular headers are to be determined by the formula in J 221.

The scantlings of flat end plates for small circular pressure vessels and heat exchangers are to be determined by the formula in J 240 taking C as the inside diameter in mm (in) and using a C value of 0,33.



Type	Acceptable for
(d) & (e)	Class 3 pressure vessels
Others	Classes 1, $2/1$, $2/2$ and 3 pressure vessels

Fig. J 3.1 Typical Acceptable Methods of Attaching Dished Ends to Cylindrical Shells

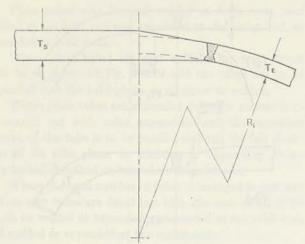
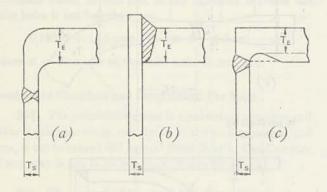


Fig. J 3.2 Attachment of Hemispherical End to Cylindrical Shell



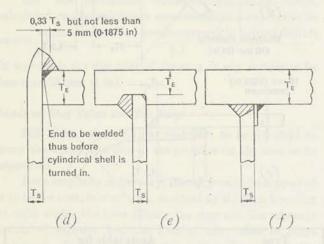


Fig. J 3.3 Typical Acceptable Methods of Attaching Unstayed Flat Ends to Cylindrical and Rectangular Headers, Small Pressure Vessels and Heat Exchangers

End types (a), (b) and (c) are to be used for headers, see Fig. J 2.13.

Standpipes

311 For acceptable methods of attaching flanges to standpipes and service limitations of the various types, see Fig. J 3.4.

Where flanges are secured by screwing, the branch and flange are to be screwed with a vanishing thread, and the diameter of the screwed portion of the branch over the thread is not to be less than the outside diameter of the unscrewed branch.

After the flange has been screwed hard home the branch is to be expanded into the flange.

The vanishing thread on a branch is not to be less than three pitches in length and the diameter at the root of the thread is to increase uniformly from the standard root diameter to the diameter at the top of the thread. This may be produced by suitably grinding the dies, and the flange should be tapered out to the same formation.

Welded Attachments to Pressure Vessels

312 Doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded and are to be provided with a "tell-tale" hole not greater than 9,5 mm (0·375 in) in diameter open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel or as a means of indicating any leakage during hydraulic testing and in service. See also J 512.

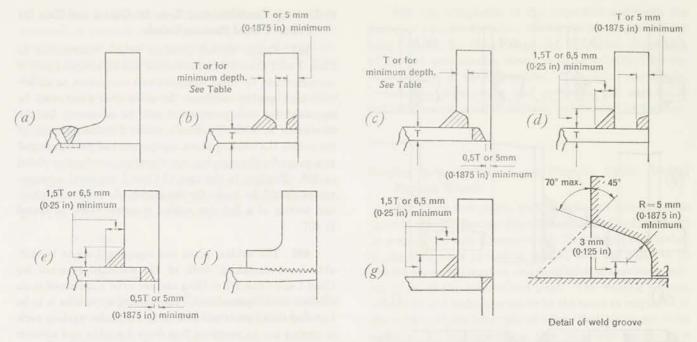
For acceptable methods of attaching standpipes, branches, compensating plates and pads, see Fig. J 3.5.

Alternative methods of attachment may be accepted provided details are submitted for consideration.

Fitting of Tubes in Water Tube Boilers

313 The tube holes in drums or headers are to be formed in such a way that the tubes can be effectively tightened in them. Where the tube ends are not normal to the tube plates, there is to be a neck or belt of parallel seating of at least 13 mm (0.5 in) in depth measured in a plane through the axis of the tube at the holes. Where the tubes are practically normal to their plates, this parallel seating is not to be less than 9.5 mm (0.375 in) in depth.

Tubes are to be carefully fitted in the tube holes and secured by means of welding, expanding and belling or by other approved methods. Tubes are to project through the neck or belt of parallel seating by at least 6 mm (0·25 in) and where they are secured from drawing out by means of bellmouthing only the included angle of belling is not to be less than 30°.



Pipe Bore	Minimum Depth of Groove for Flanges (b) and (c)	
13 mm and 19 mm	6,5 mm	
(0·5 in and 0·75 in)	(0·25 in)	
25 mm to 38 mm	8 mm	
(1 in to 1.5 in)	(0·3125 in)	
50 mm and over	9,5 mm	
(2 in and over)	(0·375 in)	

	Service and Rating						
Type of Flange Attachment	Feed, A	ir, Oil Fuel her fluids	Steam				
	Pressure kg/cm ² (lb/in ²)	Temperature °C (°F)	Pressure kg/cm ² (lb/in ²)	Temperature °C (°F)			
(a)	All Conditions		All Co	nditions			
(b) & (c)	All Conditions		52,5 (750)	454 (850)			
(d) & (e)	52,5 (750)		38,5 (550)	400			
(f)) 42 260 (600) (500)		31,5 (450)	400 (750)			
(g)	17,5 (250)		17,5 (250)	260 (500)			

Fig. J 3.4 Acceptable Methods of Attaching Flanges to Steel Branches or Standpipes

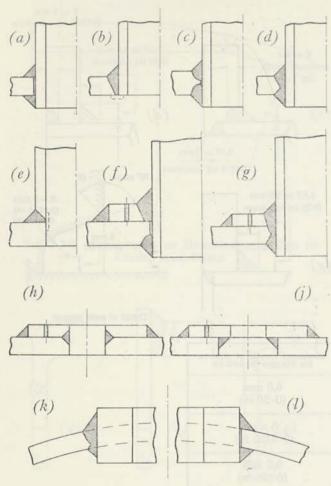


Fig. J 3.5 Typical Acceptable Methods of Attaching Branches and Pads

Types (a) and (l) attachments are not to be used for openings which require to be compensated. Backing rings may be used with types (b) and (e)

Section 4

REQUIREMENTS FOR FUSION WELDING

For list of manufacturers of Class 1 Welded Pressure Vessels, see appendix to this Chapter.

General

401 The term "fusion weld" is for the purpose of these requirements, applicable to welded joints made by the metal arc process with covered electrodes or other electric arc process in which the arc stream and the deposited metal are shielded from atmospheric contamination. The welding may be done by hand or by machine.

Preliminary Conditions and Tests for Class 1 and Class 2/1 Fusion Welded Pressure Vessels

402 Fusion welded pressure vessels constructed to Class 1 and Class 2/1 requirements will be accepted only if manufactured by firms equipped and competent to undertake high quality welding. In order that firms may be approved for this purpose, it will be necessary for the Surveyors to visit the firm's works for the purpose of inspecting the welding plant, equipment and procedure and to arrange for the carrying out of preliminary tests as stated in 405. Further, in the case of Class 1 approval, arrangements should be made for the survey during construction and testing of a full size welded pressure vessel as stated in 407.

403 The welding plant and equipment are to be suitable for undertaking work of the standard required for Class 1 and Class 2/1 welding and are to be maintained in an efficient working condition. The welding apparatus is to be installed under cover and so arranged that the welding work is carried out in positions free from draughts and adverse weather conditions. The procedure should include the regular systematic supervision of the welding work, and the welding operators are to be subjected by the work's supervisors to periodic tests for quality of workmanship. Records of these tests are to be kept and are to be available for inspection by the Surveyors.

404 The works should be equipped with an efficient testing laboratory which should include apparatus suitable for carrying out tensile, bend and impact tests, microexamination of specimens and X-ray examination of pressure vessels. The works should also be equipped with a suitable heat-treating furnace having satisfactory means for temperature control.

Alternative arrangements which, in the opinion of the Surveyors, ensure an equally high standard of quality control may be submitted for consideration.

405 Preliminary tests to demonstrate the quality of the welding work are to be carried out by the firm under the supervision of the Surveyors. The test requirements will be based on the grades of steels, and on the welding process to be used. For approval purposes, the grades of rolled steel plates specified in Q 3 shall be grouped as follows:—

- Group 1. Carbon and carbon manganese steels 37 to 57 kg/mm² (23·5 to 36·2 ton/in²).
- Group 2. Carbon and carbon manganese steels 52 to 62 kg/mm² (33 to 39·4 ton/in²).
- Group 3. Low alloy steels.

Further, the maximum plate thickness which would be approved in pressure vessel construction would depend on the thickness of the test plates used in the preliminary tests; the test plates are, however, to be at least 20 mm (0.75 in) thick.

The test plates and the full size pressure vessel mentioned in 407 are to be representative as regards materials and approximate shell thickness of the production vessels for which approval is desired.

The welded seams of the test plates are to be radiographed and the Surveyors are to select portions of the test plates containing the welded joint from which specimens are to be provided for the following tests:—

- 1. (a) Tensile
 - (b) Bend
 - (c) Hardness
 - (d) Impact | For Class 1 application and for
 - (e) Fatigue | steels in groups 2 and 3,
- Micrographs at 100 and 300 magnifications, of weld centre, fusion zone and parent plate.—For Class I application and for steels in groups 2 and 3,
- 3. Macrograph of full section weld,
- 4. Chemical analysis of deposited weld metal,
- Chemical analysis of test plates.

Note. Where the welding is carried out by an established and approved process, the fatigue tests and micrographs, 1 (e) and 2 above will not in general be required. Further, as an alternative to 5, a guaranteed analysis obtained from the steel makers will be accepted.

- 406 If a firm intends to manufacture pressure vessels either of a different group of steel, or by means of a different welding process than used in the preliminary tests on which the original approval was based, further tests will be required to cover the proposed welding procedure. In such cases, full details of the material, plate thickness and welding process proposed are to be submitted for consideration when the requirements for further preliminary tests will be indicated.
- 407 Where firms desire their name to be included in the Society's list of firms recognised by the Committee as experienced manufacturers of Class 1 fusion welded pressure vessels, they should make application at the initial stages of having their works approved. In addition to the preliminary tests, a full size pressure vessel is to be constructed in accordance with the requirements of these Rules for Class 1 fusion welded pressure vessels under the supervision of the Surveyors.

408 On completion of the inspection and tests, the Surveyor's report, including the results of the preliminary tests and also, for Class 1 approval, the results of the tests of the full size pressure vessel, is to be submitted for the consideration of the Committee. The report should also include the radiographs and particulars of any fusion welded pressure vessels previously constructed by the firm.

Routine Tests for Class 1 and Class 2/1 Fusion Welded Pressure Vessels

409 Two test plates, each of sufficient dimensions to provide one complete set of specimens required by 413, should be prepared for each pressure vessel. They should be attached to the shell plate in such a manner that the edges to be welded are a continuation and simulation of the corresponding edges of the longitudinal joint. The welding process, procedure and technique are to be the same as employed in the welding of the longitudinal joint. Test plates are to be so supported, during welding, that warping is reduced to a minimum.

Alternatively, one test plate may be prepared to provide all the test specimens required by 413 and for retest pieces.

- 410 The test plates are to be straightened before being subjected to heat treatment and for this purpose the test plates may be heated to a temperature below that required for the final heat treatment.
- 411 Test plates need not be prepared for the circumferential seams, except in cases where a pressure vessel has circumferential seams only, or where the process for welding the circumferential joints is significantly different from that used for the longitudinal joints; when one test plate is to be prepared having a welded joint which so far as possible is a simulation of the circumferential seams. The test plate is to provide all the test specimens required by 413 and for retest pieces.

Where a number of similar vessels are made at the same time it will suffice if test plates are provided for each 30 m (100 ft) of circumferential welded seam.

412 The test plates are to be cut from the shell plate or plates forming the appropriate seam and before being detached are to be stamped by the Surveyor.

When there is insufficient material available on the shell plates for the provision of test plates, acceptance may be given to test plates cut from another plate provided this plate is from the same cast and in the same heat treatment condition.

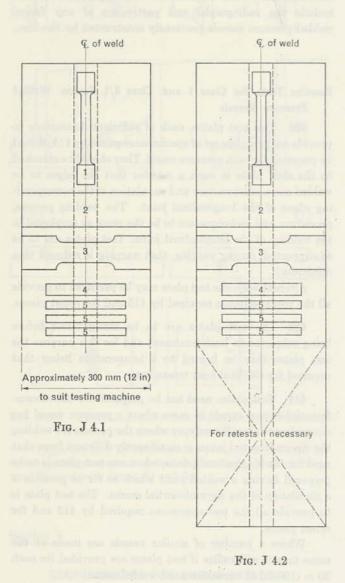
The thickness of test plates is to be the same as that of the pressure vessel.

413 One set of test specimens is to be cut from the test plates as shown in Fig. J 4.1 or Fig. J 4.2 for Class 1 pressure vessels, or as shown in Fig. J 4.3 or Fig. J 4.4 for Class 2/1

pressure vessels. The results of the tests are to comply with the requirements detailed in 415 to 419,

E of weld

& of weld



Approximately 300 mm (12 in) to suit testing machine

For retests if necessary

Fig. J 4.3

TEST PLATES FOR CLASS 1 VESSELS

- 1. All weld metal tensile test specimen.
- 2. Bend test specimens.
- 3. Tensile test for joint.
- 4. Macro test specimen.
- 5. Charpy impact test specimens.

TEST PLATES FOR CLASS 2/1 VESSELS

Fig. J 4.4

- 1. All weld metal tensile test specimen.
 - 2. Bend test specimens.
 - 3. Tensile test for joint.
 - 4. Macro test speciment.

Retests

414 If any of the tests fail, the reason for the failure is to be investigated and two retest specimens are to be prepared and tested. Where two test plates have been prepared, the retests are to be cut from the second test plate. If it can be shown that the failure of the initial test has resulted from local or accidental defect and the retest values are satisfactory, the retest values may be accepted.

Tensile Test for all Weld Metal. Specimen No. 1

415 One all weld metal tensile specimen is to be taken for Class 1 pressure vessels having a shell thickness not exceeding 70 mm (2.75 in) and for all Class 2/1 pressure vessels. (The latter pressure vessels are restricted by J 107 to a maximum shell thickness of 38 mm (1.5 in)). Where the shell thickness of a Class 1 pressure vessel exceeds 70 mm (2.75 in), two such specimens are to be taken one above the other.

The diameter of the all weld metal test piece at the reduced parallel position is to be not less than 14 mm (0.564 in) except in the case of thin plates where the largest practicable diameter should be used. The gauge length of the test piece is to be five times the diameter.

The dimensions of the all weld metal test specimen are shown in Fig. J 4.5a and their location when two specimens are used in Fig. J 4.5b.

The tensile strength of the weld metal is not to be less than the minimum and not more than 15 kg/mm² (9.25 ton/in²) above the minimum specified for the plate.

The percentage elongation A is not to be less than given by:—

$$A = \frac{100 - R}{2,2}$$

where R is the tensile strength in kg/mm² $\left(\frac{lb/in^2}{1422}\right)$

In addition, this elongation is not to be less than 80 per cent of the equivalent elongation specified for the plate.

Transverse Bend Test. Specimen No. 2

416 Two bend test specimens of rectangular section are to be cut from the test plate transversely to the weld, one to be bent with the outer surface of the weld in tension, and the other with the inner surface in tension.

The specimens are to have a width equal to 1,5 times the thickness of the specimen and the mid-portion is to coincide with the centre line of the weld. The edges are to be rounded to a radius not exceeding 10 per cent of the thickness.

Where the plate thickness does not exceed 30 mm $(1 \cdot 2 \text{ in})$ the thickness of the specimens are to be the full thickness of the plate. Where the plate thickness exceeds 30 mm $(1 \cdot 2 \text{ in})$ the specimens, in all cases, are to have a

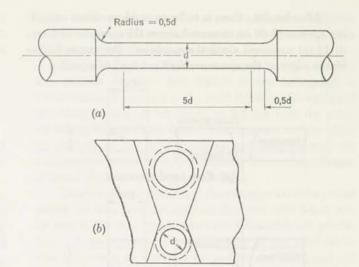


Fig. J 4.5 Specimen No. 1 Tensile Test for all Weld Metal

thickness of 30 mm (1·2 in) and are to be prepared by discarding metal from the surfaces which will be in compression when the test is applied. See Figs. J 4.6a and J 4.6b.

Where the thickness of the plate permits, the bend specimens may be prepared as shown in Fig. J 4.6c.

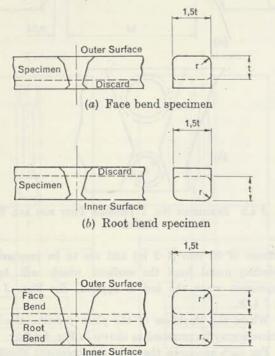
For each specimen the weld reinforcement should be removed by grinding or machining so that the outer and inner surfaces of the weld are flush with the surface of the plate.

The specimen is to be mounted on roller supports with the centre of the weld midway between the supports. A former, with its axis perpendicular to the specimen, is to bend the specimen by pushing it through the clear space between the supports. The diameter of the former and the clear space between the supports will depend on the thickness of the specimens and these dimensions are shown in Table J 4.1 in terms of T the thickness of the specimen.

TABLE J 4.1

	ed Tensile Strength Plate	Diameter	Clear Space between	
kg/mm²	(ton/in ²)	Former	Supports	
Under 47	(29 · 8)	2T	4,2T	
47 and under 52	(29·8 and under 33·0)	3T	5,2T	
52 and not exceeding 63	(33·0 and not exceeding 40·0)	4T	6,2T	

After bending there is to be no crack or defect exceeding 1,5 mm (0.06 in) measured across the specimen or 3 mm (0.12 in) measured along the specimen. Premature failure at the edges of the specimen shall not lead to rejection.



(c) Face and root bend specimen cut from single piece of plate Fig. J 4.6 Specimen No. 2 Bend Test

Tensile Test for Joint. Specimen No. 3

417 One reduced section tensile test specimen is to be cut transversely to the weld, or in thick plate, as many tensile test specimens as may be necessary to investigate the tensile strength throughout the whole thickness of the joint. The weld reinforcement should be removed by grinding or machining so that the outer and inner surfaces of the weld are flush with the surface of the plate. The dimensions of the reduced section tensile test specimens are shown in Fig. J 4.7. The width B at the reduced section is to be at least 25 mm (1 in).

Where the plate thickness exceeds 30 mm (1·2 in) the tensile test may be effected on several reduced-section

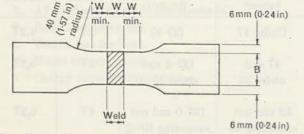


FIG. J 4.7 SPECIMEN No. 3 TENSILE TEST FOR JOINT

specimens each with a thickness of at least 30 mm (1·2 in) and a width at the effective cross-section of at least 25 mm (1 in).

The tensile strength obtained is not to be less than the minimum specified tensile strength for the plate material.

Macro Specimen. Specimen No. 4

418 Macro etching of a complete cross-section of the weld including the heat affected zone is to show a satisfactory penetration and an absence of lack of fusion, significant inclusions or other defects.

Should there be any doubt as to the condition of the weld as shown by macro etching, the area concerned is to be microscopically examined.

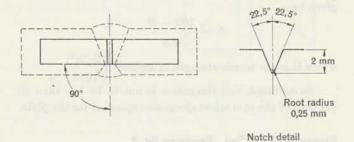
Notched Bar Impact Test. Specimen No. 5. Class 1 only

419 Three Charpy V-notch impact test specimens are to be cut transversely to the weld, parallel to the plate surface and at mid-plate thickness. The notch is to be cut at approximately the centre of the weld and the axis of the notch is to be perpendicular to the surface of the plate.

The dimensions of the specimens are as shown in Fig. J 4.8.

The minimum result obtained from the Charpy V-notch test specimens is not to be less than 2,77 kg m (20 ft lb) when the temperature of the specimen at the time of test does not exceed 50°C (122°F).

Where it is proposed to use impact tests other than Charpy V-notch tests, details should be submitted for consideration.



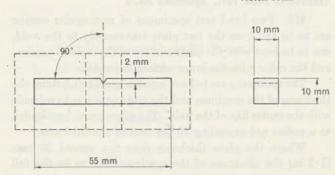


Fig. J 4.8 Specimen No. 5 Charpy V-Notch Impact Test Specimen

The foregoing impact tests are not applicable to pressure vessels operating at low metal temperatures, and for such cases the results of the weld metal impact tests will be specially considered (see J 703).

NON-DESTRUCTIVE EXAMINATION

Radiographic Examination

420 The extent of the radiographic examination of the welded seams of Class 1 and Class 2/1 pressure vessels are to be as follows:—

- (a) Class 1 Pressure Vessels. All butt welded seams in drums, shells, headers and pipes and tubes over 170 mm (6·625 in) outside diameter, together with the test plate or plates, are to be subjected to 100 per cent radiographic examination. For circumferential butt welds in extruded connections, pipes, tubes, headers and other tubular parts 170 mm (6·625 in) outside diameter and less, 10 per cent of the total number of welds are to be radiographed. See also 426.
- (b) Class 2/1 Pressure Vessels. Spot radiographs are to be taken at selected regions of each main seam. The test plate or plates are to be fully radiographed and at least 10 per cent of the length of each main seam is to be so examined. See also 427.

Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure, are to be subject to spot radiographic examination.

Where the surface finish of any weld which has to be radiographed is such that it will prevent accurate radiographic examination, the surface is to be machined or ground to provide a smooth contour to the Surveyor's satisfaction.

421 Lead type is to be fixed to the plate adjacent to the weld so that each radiograph is marked in such a way that the corresponding portion of the welded seam can be readily and accurately identified.

The length of weld covered by each exposure is to be such that the metal thickness along the incident beam at the extremity of the exposure is not to exceed the actual thickness by more than 10 per cent.

422 Image quality indicators (penetrameters) of an approved type are to be placed at each end of each radiograph and on the surface of the plate facing the source of radiation.

Image quality indicators of the step hole type are to be placed alongside the welded seam parallel to its length and are to have a hole in each step of a diameter corresponding to its thickness at that step or are to have some similar device whereby the step thickness can be identified when the radiographic film is examined.

The radiographic technique employed is to be such that the smallest diameter hole visible in the radiograph is not to exceed 3 per cent of the weld thickness for welds not exceeding 50 mm (2 in) thick, or 2,5 per cent for welds exceeding 50 mm (2 in) thick. The steps are to bear these proportions to the weld thickness radiographed and the radiographic technique is to be capable of revealing changes of metal thickness of these percentages.

Image quality indicators of the wire type are to be placed across the weld and the smallest diameter wire which can be seen in the radiograph is to have a diameter not greater than 1,5 per cent of the weld thickness, if the weld thickness is between 10 mm (0.4 in) and 50 mm (2 in) and not greater than 1,25 per cent of the weld metal thickness if the thickness exceeds 50 mm (2 in) up to 200 mm (7.875 in).

The use of gamma rays may be permitted in certain circumstances when details should be submitted for consideration and approval.

423 Radiographs are to be examined by the Surveyors on the original films using a viewing device of suitable illuminating power.

Ultrasonic Examination

424 In Class 1 pressure vessels where the plate thickness exceeds 65 mm (2·5 in), ultrasonic examination may be accepted as an alternative to radiographic examination. Such examination is to be affected by an approved operator using an approved technique incorporating autographic recording of flaw signals and coupling reliability. Supplementary examination by radiography at selected locations may be required in certain cases.

Magnetic Crack Detection

425 In Class 1 and Class 2/1 pressure vessels the welds on standpipes, compensating plates, stubs and branches, etc., of ferritic steels, which have not been radiographed are to be magnetically crack detected at the rate of 10 per cent of such welds. This rate may be increased or decreased at the discretion of the Surveyors. For non-magnetic materials dye penetrant examination will be accepted.

Repairs to Welded Seams

426 In the case of Class 1 pressure vessels when nondestructive tests show unacceptable defects in the welded seams, the defects are to be repaired and are to be shown by further non-destructive tests to have been eliminated to the Surveyor's satisfaction. 427 In the case of Class 2/1 pressure vessels, when a spot radiograph reveals unacceptable defects in a welded seam, at least two further radiographs are to be made in the length of weld represented by the first radiograph in locations selected by the Surveyor. If these reveal no further unacceptable defects, the defects revealed by the first radiograph are to be repaired and re-radiographed. If the check radiographs reveal unacceptable defects either:—

- (a) the whole length of weld represented is to be cut out and re-welded, then subjected to spot radiography as if it were a new weld, and the original test plates associated with the weld are to be similarly treated, or
- (b) the whole length of weld represented is to be radiographed. Unacceptable defects are to be repaired and are to be shown by radiography to have been eliminated.

Preliminary Conditions and Tests for Class 2/2 Fusion Welded Pressure Vessels

428 Pressure vessels made in accordance with Class 2/2 requirements will be accepted only if constructed by firms whose works are properly equipped to undertake the welding of pressure vessels of this Class.

The welding plant is to be installed under cover and is to be maintained in an efficient working condition and adequate supervision of the welding work is to be provided.

It will be necessary for the Surveyors to visit the firm's works for the purpose of inspecting the welding plant, equipment and procedure and to arrange for the carrying out of preliminary tests similar to those described in 436, 437 and 438.

On completion of the inspection and tests, the Surveyor's report including the results of the preliminary tests and particulars of the fusion welded pressure vessels previously constructed by the firm are to be submitted for the consideration of the Committee.

Routine Tests for Class 2/2 Fusion Welded Pressure Vessels

429 Two test plates each of sufficient dimensions to provide one complete set of specimens required by 434 should be prepared for each pressure vessel. They should be attached to the shell plate in such a manner that the edges to be welded are a continuation and simulation of the corresponding edges of the longitudinal joint. The welding

process, procedure and technique are to be the same as employed in the welding of the longitudinal joint. Test plates are to be so supported during welding that warping is reduced to a minimum.

Alternatively, one test plate may be prepared to provide all the test specimens required by 434 and for retest pieces.

430 In cases where a number of Class 2/2 pressure vessels are made concurrently at the same works, and the plate thicknesses do not vary by more than 5 mm (0·19 in), each 37 m (120 ft) of welded seam, longitudinal plus circumferential, may be regarded as equivalent to one pressure vessel, the required number of test specimens being provided accordingly.

In these cases the thickness of the test plates is to be equal to that of the thickest shell plate used in the construction of the pressure vessels.

- 431 The test plates are to be straightened before being subjected to heat treatment and for this purpose the test plates may be heated to a temperature below that required for the final heat treatment.
- 432 Test plates need not be prepared for the circumferential seams, except in cases where a pressure vessel has circumferential seams only, or where the process for welding the circumferential joints is significantly different from that used for the longitudinal joints, when one test plate is to be prepared having a welded joint which, so far as possible, is a simulation of the circumferential seams. The test plate is to provide all the test specimens required by 434 and for retest pieces.

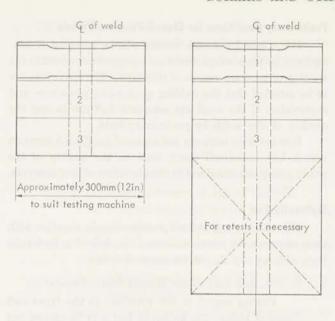
Where a number of similar vessels are made at the same time, it will suffice if test plates are provided for each 30 m (100 ft) of circumferential welded seam.

433 The test plates are to be cut from the shell plate or plates forming the appropriate seam and before being detached are to be stamped by the Surveyor.

When there is insufficient material available on the shell plates for the provision of test plates, acceptance may be given to test plates cut from another plate provided this plate is from the same cast and in the same heat treatment condition.

The thickness of test plates is to be the same as that of the pressure vessel.

434 One set of test specimens is to be cut from the test plates as shown in Fig. J 4.9 or Fig. J 4.10. The results of the tests are to comply with the requirements detailed in 436, 437 and 438.



TEST PLATES FOR CLASS 2/2 VESSELS

Fig. J 4.10

1. Tensile test for joint.

Fig. J 4.9

- 2. Bend test specimens.
- 3. Nicked bend test specimen.

435 If any of the tests fail, the reason for the failure is to be investigated and two retest specimens are to be prepared and tested. Where two test plates have been prepared, the retests are to be cut from the second test plate. If it can be shown that the failure of the initial test has resulted from local or accidental defect and the retest values are satisfactory, the retest values may be accepted.

Tensile Test for Joint

436 The shape and preparation of the specimen are to conform to the requirements of 417.

The tensile strength obtained is not to be less than the minimum specified tensile strength for the plate material.

Transverse Bend Tests

437 The shape and preparation of the specimens and the procedure for testing are to comply with the requirements of 416 as applicable to the grade of steel permitted by Table J 1.1.

Nicked Bend Tests

438 The specimen is to have a slot cut into each side on the centre line of the weld and perpendicular to the plate surface. The specimen is then to be broken in the weld and the fracture is to reveal a sound homogeneous weld, substantially free from slag inclusions, porosity and coarse crystallinity.

Post-Welding Heat Treatment

Note.—For heat treatment on completion of the forming of shell sections and end plates, see J 504.

439 Depending upon the grade of steel and plate thickness, Class 1, Class 2/1 and Class 2/2 pressure vessels, where indicated in Table J 4.2, are to be efficiently heat treated on completion of the welding of the seams and of all attachments to the shell and ends and before the hydraulic test is carried out.

TABLE J 4.2

Grade of	Те	nsile Range	Plate thicknesses at and above which post-welding heat treatment is required				
Steel	kg/mm ²	(ton/in2)	Class 1	Class 2/1	Class 2/2		
Carbon	37-47	(23 · 5 – 29 · 8)	20 mm (0·75 in)	See Note below	See Note below		
and	42-52	$(26 \cdot 7 - 33 \cdot 0)$	20 mm (0·75 in)	32 mm (1·25 in)	32 mm (1·25 in)		
Carbon-	47-57	$(29 \cdot 8 - 36 \cdot 2)$	20 mm (0·75 in)	25 mm (1 in)	_		
manganese	52-62	(33 · 0 – 39 · 4)	20 mm (0·75 in)	20 mm (0·75 in)	-		
Low alloy steels	_	-	All thicknesses to be heat treated	-	===		

Note.—The maximum thickness of Class 2/1 and Class 2/2 pressure vessels is limited to 38 mm (1.5 in) and heat treatment is not required for carbon and carbon-manganese steels in the tensile range 37–47 kg/mm² (23.5–29.8 ton/in²).

440 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means for temperature control and is fitted with pyrometers which will measure and record the temperature of the furnace charge. The heat treatment is to consist of heating the vessel slowly and uniformly to a suitable stress relieving temperature, soaking for a suitable period, followed by cooling slowly and uniformly in the furnace to a temperature not exceeding 400°C (750°F) and subsequently cooling in a still atmosphere. The temperature and soaking periods are to be selected which will relieve residual stress without undue reduction of the properties of material.

Recommended soaking temperatures and periods are given in Table J 4.3.

In cases where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

- 441 Where pressure vessels are of such dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections provided sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.
- 442 Test plates should be heat treated in the same furnace and at the same time as the pressure vessels which they represent. In special cases, however, it may be permissible to heat treat the test plates separately from the pressure vessels provided the Surveyor is satisfied with the means adopted to ensure that the following factors will be the same for the pressure vessels as for their respective test plates:—

Rate of heating,
Maximum temperature,
Time held at maximum temperature,
Conditions of cooling.

443 Where it is proposed to adopt special methods of heat treatment full particulars are to be submitted for consideration. In such cases it may be necessary to carry out tests to show the effect of the proposed heat treatment.

Preliminary Conditions for Class 3 Pressure Vessels

444 Class 3 pressure vessels will be accepted if constructed by firms whose works are equipped to undertake the welding of pressure vessels of this type. The Surveyors are to be satisfied that the welding equipment, procedure and supervision of the work are adequate and are to test the quality of the welds by preliminary tests.

Routine weld tests are not required for Class 3 pressure vessels but occasional check tests on the quality of the welding may be carried out at the discretion of the Surveyors.

Hydraulic Test

445 Boilers and unfired pressure vessels, together with their components, are to withstand the following hydraulic tests without any sign of weakness or defect.

1. Boilers, including Steam Heated Steam Generators.

Having regard to the variation in the types and design of boilers, the hydraulic test may be carried out by either of the methods indicated below:—

- (i) The boiler on completion is to be tested to a pressure of 1,5 times the design pressure, or
- (ii) (a) Where construction permits, all components of the boiler are to be tested on completion of the work including heat treatment to 1,5 times the design pressure. In the case of components such as drums or headers, which are to be drilled for tube holes, the test may be made before drilling the tube holes but is to be after the attachment of standpipes, stubs and similar fittings and also after heat treatment has been carried out,
 - (b) Provided all the components have been tested as in (a) above, each completed boiler after assembly is to be tested to 1,25 times the design pressure.

Where any of the components have not been tested as in (a) above, each completed boiler after assembly is to be tested to 1,5 times the design pressure.

TABLE J 4.3

Type of Steel	Soaking Temperatures	Time at Temperature per 25 mm (1 in) of Thickness 1 hour—min. period 1 hour	
Carbon Carbon-manganese	580–620°C (1080–1150°F)		
1 Cr ½ Mo	620-660°C (1150-1220°F)	1 hour—min. period 2 hours	
21 Cr 1 Mo	650-690°C (1200-1270°F)	2 hours—min. period 2 hours	

2. Unfired Pressure Vessels.

Unfired pressure vessels are to be tested on completion to a pressure, P_T, which is to be determined by the following formula:—

$${\rm P_{T}\,=\,1.3\,\frac{f_{100}}{f_{\rm d}}\frac{T}{(T\!-\!C)}\,{\rm P}}$$

but is in no case to exceed 1,5 $\frac{\mathsf{T}}{(\mathsf{T}-\mathsf{C})}\,\mathsf{P}$

where $P_T = \text{test pressure}$, in kg/cm² (lb/in²),

P = design pressure, in kg/cm² (lb/in²),

T = nominal thickness of shell as indicated on the plan, in mm (in),

C = corrosion allowance to be taken as 0.75 mm (0.03 in),

 f_{100} = allowable stress at 100°C (212°F), in kg/cm^2 (lb/in²),

f_G = allowable stress at design temperature, in kg/em² (lb/in²).

Section 5

MANUFACTURE AND WORKMANSHIP

FUSION WELDED PRESSURE VESSELS

Note. The following requirements are applicable to all classes of fusion welded pressure vessels except where otherwise indicated.

Electrodes

501 Electrodes intended for use in the construction of pressure vessels are to be stored in a dry place. In order to ensure that the quality of electrodes is being consistently maintained they are to be subjected to a regular system of periodic testing and inspection. Where routine tests are frequently carried out in respect of pressure vessels made in the normal course of production, such tests may be regarded as meeting the requirements of this paragraph.

Welding Equipment

502 All welding plant and auxiliary equipment is to be maintained in good working order and adequate means of measuring current are to be provided. In the case of machine welding, means are to be provided for measuring the arc voltage. All electrical plant used in connection with the welding operation is to be adequately earthed.

Plate Cutting

503 Plates are to be cut to size and shape by machine flame cutting and/or machining. Where the plate thickness

does not exceed 25 mm (1 in) cold shearing may be used provided that the sheared edge is cut back by machining or chipping for a distance of one quarter of the plate thickness but in no case less than 3 mm (0.125 in).

All plate edges, after cutting and before carrying out further work upon them are to be examined for laminations, and also to ensure that any sheared edges are free from cracks. Visual methods may be supplemented by other techniques at the discretion of the Surveyor.

Forming Shell Sections and End Plates

504 Plates for shell sections and end plates are to be formed to the required shape by any process that will not impair the quality of the material. Tests to demonstrate the suitability of a process may be required at the discretion of the Surveyors.

Shell plates are to be formed to the correct contour up to the extreme edges of the plate. So far as possible, hot and cold forming is to be done by machine; forming by hammering with or without local heating is not to be employed.

All plates which have been hot formed or locally heated for forming are to be normalised on completion of this operation. If, however, hot forming is carried out entirely at a temperature within the normalising range, subsequent heat treatment will not be required for carbon steels. In both instances alloy steels may, in addition, require to be tempered.

All plates which have been cold formed to an internal radius less than 10 times the plate thickness are to be given an appropriate heat treatment.

Preparation of Plate Edges and Openings for Welding

505 Welding preparations and openings of the required shapes may be formed by the following methods:—

- (a) Machining, chipping or grinding; chipped surfaces which will not be covered with weld metal are to be ground smooth after chipping.
- (b) Flame cutting.

Special examination will be required for cracks on the cut surfaces and the heat affected zones in flame cut alloy or high carbon steels; preheating may be required in order to ensure satisfactory results when flame cutting.

Any material damaged in the process of cutting plates to size or forming welding grooves is to be removed by machining, grinding or chipping back to sound metal. Surfaces which have been flame cut are to be cut back by machining or grinding so as to remove all burnt metal, notches, slag and scale, but slight discolouration of machine flame cut edges on mild steel is not to be regarded as detrimental. If allow steels are prepared by flame cutting the

surface is to be dressed back by grinding or machining for a distance of at least 1,6 mm (0.0625 in) unless it has been shown that the material has not been damaged by the cutting process.

506 After edges of the plates have been prepared for welding they are to be carefully examined for flaws, cracks, laminations, slag inclusions or other defects.

507 Care is to be taken to ensure that the weld preparations are correctly profiled.

Assembly of Plates for Welding

508 The plates are to be assembled and retained in position for welding by any suitable method; tack welds, where used, are to be removed so that they do not become part of the seam. Correction of irregularities is not to be carried out by hammering.

Where a root gap is specified the edges of butt welds are to be held so that the correct gap is maintained during welding.

Where welded-on bridge pieces or other aids to fabrication are used, care is to be taken that the surfaces of the material are not left in a damaged condition after the attachments have been removed. Any necessary removal of attachments and rectification of scars by welding is to be undertaken before applying post-weld heat treatment.

Butt Welds in Plates of Equal Thickness

509 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other at any point by more than 10 per cent of the plate thickness, but in no case is the misalignment to exceed 3 mm (0·125 in) for longitudinal seams or 4 mm (0·156 in) for circumferential seams.

Butt Welds in Plates of Unequal Thickness

510 Where a drum is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be arranged so that their centre lines form a continuous circle. For the longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in the thicknesses so that the two plates are of equal thickness at the position of the longitudinal weld. For the circumferential seam, the thicker plate is to be similarly prepared over the same distance longitudinally.

For the circumferential seam, where the difference in the thicknesses is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other at any point by more than 10 per cent of the thickness of the thinner plate, but in no case is the misalignment to exceed 3 mm (0.125 in) for longitudinal seams or 4 mm (0.156 in) for circumferential seams.

Plates Welded Prior to Forming

511 Seams in plates may be welded prior to forming provided on completion of forming and subsequent heat treatment they meet the specified mechanical test requirements and that they are examined radiographically throughout their length after forming (see, however, J 424). After forming, the surfaces of such seams in alloy steel parts, also carbon steel parts over 25 mm (1 in) in thickness, are to be ground smooth and inspected for cracks by magnetic crack detection, dye penetrants or other means at the discretion of the Surveyor.

Attachments and Fittings

512 All lugs, brackets, branches, manhole frames and reinforcements around openings and other members are to conform to the shape of the surface to which they are attached.

The attachment by welding of such fittings to the main pressure shell after post-weld heat treatment is not permitted, except where the material involved is mild steel when welding will only be permitted provided it is necessitated by the method of construction being employed and prior approval of the Surveyor must be obtained before any welding is carried out. In no circumstances is any welding to be done after heat treatment on vessels made of carbon or carbon-manganese steel with tensile strength exceeding 52 kg/mm² (33 ton/in²) or of alloy steel.

When the fittings referred to above (see also J 312), together with flats and other attachments for supporting internal and external components, are welded to the main pressure shell, the welding is to be of comparable standard to that required for the vessel and the material used is to be of compatible composition.

The finish of all welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to permit satisfactory examination of the welds. In the case of Class 1 pressure vessels these welds are to be ground smooth, if necessary, to provide a suitable finish for crack detection tests which are to be carried out to the Surveyor's satisfaction on completion of the hydraulic test.

Welding of Main Seams

- 513 When welding with the manual metal arc and submerged arc welding processes, the following requirements are to be applied. When other processes are utilised it may be necessary to modify or amplify these precautions to ensure satisfactory workmanship.
 - (a) All surfaces to be welded are to be thoroughly cleaned of scale, rust, oil or other foreign matter down to a clean surface for a distance of at least 12,5 mm (0·5 in) from the welding edge. Welding grooves are to be similarly cleaned.
 - (b) Unless otherwise approved seams are to be welded from both sides of the plate. When manual arc welding is employed, the metal at the bottom of the first side is to be removed by grinding, chipping, machining or other approved methods so as to provide clean sound metal on which to deposit the subsequent welds.

The welding procedure for a butt joint welded from one side of the plate is to provide complete fusion. Special care is to be taken to ensure that the root is properly fused and that distortion due to the contraction of the weld metal is minimised.

Backing strips, if used, are to be of the same nominal composition as the plates to be welded and where practicable are to be removed and the surface dressed smooth by grinding prior to radiography.

The roots of butt joints and seams welded from one side of the plate are to be dressed smooth by grinding and before radiographic examination. The dressed surfaces are to be examined for root defects.

- (c) Each run of weld metal is to be thoroughly cleaned and all slag removed before the next run is deposited.
- (d) After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly clean and free from slag, and that there is proper penetration into the plates and the previously deposited weld metal.
- (e) Welding is to be carried out in the downhand horizontal position. In the case of circumferential seams means are to be adopted to ensure compliance with this requirement.
- (f) Fillet welds are to be made so as to ensure proper fusion and penetration of the weld metal at the root of the fillet.
- (g) Not less than two runs of metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

- (h) The arc is to be struck only on those parts of the parent metal where the weld metal is to be applied or of the welding metal already deposited.
- (j) Preheating is to be employed when necessitated by the joint restraint, thickness of the plate, and composition of the material to be welded.
- (k) On completion of the welding, the seams are to be thoroughly examined before being dressed or machined. Parts showing evidence of blow-holes, slag inclusions, unsatisfactory penetration, porosity, or any other defect are to be cut out and rewelded, and undercutting made good.

The outer surfaces of the welds may be flush with the surfaces of the plates joined, but no objection will be raised if the total thickness at the centre of the weld is greater than the thickness of the plates, provided the change of section is gradual.

(l) In cases where it is proposed to adopt fusion welding processes in which it may not be possible to comply fully with the foregoing requirements regarding technique, full particulars are to be submitted for consideration.

Tolerances for Cylindrical Shells

514 The shell sections of completed vessels are to be circular within the limits defined in 516. Measurements are to be made to the surface of the parent plate and not to a weld, fitting or other raised part.

Shell sections are to be measured for out-of-roundness either when laid flat on their sides or when set up on end. When the shell sections are checked whilst lying on their sides, each measurement for diameter is to be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter are to be averaged and the amount of out-of-round calculated from the average values so determined.

There are to be no flats or peaks at welded seams and any local departure from circularity is to be gradual.

515 The external circumference of the completed shell is not to depart from the calculated circumference (based upon nominal inside diameter and the actual plate thickness) by more than the following amounts:—

TABLE J 5.1

Outside Diameter (Nominal inside diameter plus twice actual plate thickness)	Circumferential Tolerance
300 mm (12 in) up to and including 600 mm (24 in)	± 5 mm (0·1875 in)
Over 600 mm (24 in)	± 0,25 per cent

516 In assessing the out-of-roundness of pressure vessels, the difference between the maximum and minimum internal diameters measured at one cross-section is not to exceed the amount given in Table J 5.2.

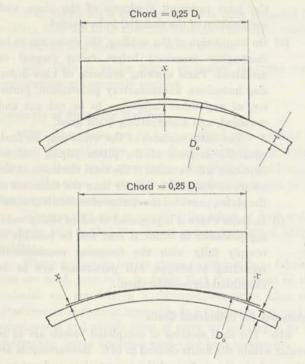


Fig. J 5.1 Tolerances for Cylindrical Shells

The profile, measured on the inside or outside of the shell by means of a gauge of the designed form of the shell and having a length equal to one quarter of the internal diameter of the vessel, is not to depart from the designed form by more than the amount given in Table J 5.2. (This amount corresponds to x in Fig. J 5.1).

Section 6

MOUNTINGS AND FITTINGS

MOUNTINGS AND FITTINGS FOR CYLINDRICAL AND VERTICAL BOILERS AND UNFIRED STEAM GENERATORS

General

601 Valves over 38 mm (1.5 in) diameter are to be fitted with outside screws and the covers are to be secured by bolts or studs. All valves are to be arranged to be shut with a right-hand (clockwise) motion of the wheels.

602 All valves and cocks connected to the boiler are to be such that it is seen without difficulty whether they are open or shut. Where boiler mountings are secured by studs, the studs are to have a full thread holding in the plate for a length of at least one diameter. If the stud hole penetrates

TABLE J 5.2

	Nominal Internal Diameter of Vessel Difference between Max, and Min. Diameters					
Over	Up to and including	Average press and	mm (in)			
-	300 mm (12 in)	1,0 per cent of	1,2 (0.046 88)			
300 mm (12 in)	460 mm (18 in)	internal	1,6 (0.0625)			
460 mm (18 in) 600 mm (24 in)		diameter	2,4 (0.093 75)			
600 mm (24 in)	900 mm (36 in)		3,2 (0.125)			
900 mm (36 in)	1220 mm (48 in)		4,0 (0.156 25)			
1220 mm (48 in)	1520 mm (60 in)		4,8 (0.1875)			
1520 mm (60 in)	1900 mm (75 in)		5,6 (0 · 218 75)			
1900 mm (75 in)	2300 mm (90 in)	19 mm (0·75 in)	6,4 (0.25)			
2300 mm (90 in)	2670 mm (105 in)		7,2 (0.281 25)			
2670 mm (105 in)	3950 mm (156 in)	19 mm (0·75 in)	8,0 (0.3125)			
3950 mm (156 in)	4650 mm (186 in)	19 mm (0·75 in)	0,2 per cent of			
3950 mm (156 in) 4650 mm (186 in) 4650 mm (186 in)		0,4 per cent of vessel internal diameter	vessel diameter			

the whole thickness of the plate the stud is to be screwed right through the plate and is to be fitted with a nut inside the boiler. Where bolts are used for securing mountings they are to be screwed right through the plate with their heads inside the boiler.

603 Where a superheater is fitted which can be shut off from the boiler it is to be provided with a separate safety valve fitted with easing gear. The valve as regards construction is to comply with the regulations for ordinary safety valves, but the easing gear may be fitted to be workable from the the stokehold only. The superheater is also to be fitted with a drain valve or cock to free it from water when necessary.

604 Safety valve chests and other boiler and superheater mountings subjected to pressures exceeding 10,5 kg/cm² (150 lb/in²) or to steam temperatures exceeding 218°C (425°F), and boiler blow down fittings, are to be made of steel or other approved material.

Safety Valves

605 Boilers and unfired steam generators are to be fitted with not less than two safety valves, each having a minimum diameter of 38 mm (1.5 in), but those having a total heating surface of less than 9,3 m² (100 ft²) may have one valve not less than 50 mm (2 in) diameter.

606 The valves, spindles, springs and compression screws are to be so encased and locked that the safety valves and pilot valves, after setting to the working pressure, cannot be tampered with or overloaded in service; the spring casing of superheater safety valves should be ventilated or other arrangement provided to protect the springs from excessive temperature.

Valves are to be so designed that in the event of fracture of springs they cannot lift out of their seats. For safety valves operating at pressures below 17,5 kg/cm² (250 lb/in²) it should, in general, be possible for the valves to be turned round on their seats by hand.

Easing gear is to be provided for lifting the safety valves and is to be operable by mechanical means at a safe position from the boiler or engine room platforms.

Safety valves are to be made with working parts having ample clearances to ensure complete freedom of movement. Valve seats are to be effectively secured in position. Any adjusting devices which control discharge capacity are to be positively secured so that the adjustment will not be affected when the safety valves are dismantled at surveys.

607 All the safety valves of each boiler and unfired steam generator may be fitted in one chest, which is to be separate from any other valve chest and is to be connected directly to the shell by a strong and stiff neck, the passage through which is not to be of less cross-sectional area than the aggregate area of the safety valves in the chest in the case of full lift valves and one-half of that area in the case of other valves. For the meaning of aggregate area, see 608.

Each safety valve chest is to be drained by a pipe fitted to the lowest part and led with a continuous fall to the bilge or to a tank, clear of the boilers. No valves or cocks are to be fitted to these drain pipes. It is recommended that the bore of the drain pipes be not less than 19 mm (0.75 in).

SATURATED STEAM

608 The minimum aggregate area of the orifices through the seatings of the safety valves on each boiler and unfired steam generator is to be found by the following formula:—

$$A = \frac{100 \text{ E}}{C (P + 1,05)}$$

$$\left(A = \frac{E}{C (P + 15)} British \right)$$

- where A = for ordinary, high lift or improved high lift safety valves, the aggregate area in mm² (in²) of the orifices through the seatings of the valves, neglecting the area of guides and other obstructions,
 - = for full lift safety valves, the net aggregate area in mm² (in²) through the seats after deducting the area of the guides or other obstructions when the valves are fully lifted,
 - P = design pressure in kg/cm² (lb/in²) gauge,
 - E = designed evaporation in kg/hour (lb/hour). In no case is the designed evaporation to be based on less than 29 kg/m² hour (6 lb/ft² hour) of heating surface for coal or oil fired boilers and 14,5 kg/m² hour (3 lb/ft² hour) for exhaust gas heated boilers.
 - C = 4,8 for valves of ordinary type having a minimum lift of D/24,
 7,2 for valves of high lift type, having a minimum lift of D/16,
 9,6 for valves of improved high lift type having a minimum lift of D/12,
 19,2 for valves of full lift type having a minimum lift of D/4,
 - D = bore of valve seat in mm (in).

When the discharge capacity of a safety valve of approved design has been established by type tests, carried out in the presence of the Surveyors or by an independent authority recognised by the Society, on valves representative of the range of sizes and pressures intended for marine application, consideration will be given to the use of a higher constant than C=19,2 based on 90 per cent of the measured capacity up to a maximum of C=45 for full lift safety valves.

SUPERHEATED STEAM

609 For valves which have to pass superheated steam, the aggregate area of the valves is to be the area A required by 608, multiplied by the factor:—

1 + 0,0018 t (1 + 0.001 t British)

where t = degree of superheat in degC (degF).

Unfired Steam Generators

610 Steam heated steam generators are to be protected from excessive pressure resulting from any failure of the high pressure heating tubes. For this purpose, the area of safety valves obtained by the formula in 608 may require to be increased unless other protective devices are provided to control the supply of steam to the heating tubes.

Waste Steam Pipes

611 For ordinary, high lift and improved high lift type valves, the cross-sectional area of the waste steam pipe and passages leading to it, is to be at least 10 per cent greater than the aggregate area of the safety valves as calculated by the foregoing formulæ. For other valves the cross-sectional area of the waste steam pipe and passages is not to be less than 0,1 C times the aggregate valve area.

The cross-sectional area of the main waste steam pipe is not to be less than the combined cross-sectional areas of the branch waste steam pipes leading thereto from the boiler safety valves.

Waste steam pipes from boilers and unfired steam generators are to be led to the atmosphere and are to be adequately supported and provided with suitable expansion joints, bends or other means to relieve the safety valve chests of undue loading.

The scantlings of waste steam pipes and silencers are to be suitable for the maximum pressure to which the pipes may be subjected in service and not less than 0,25 times the pressure to which the valves are to be set.

Silencers fitted to waste steam pipes are to be so designed that the clear area through the baffle plates is not less than that required for the pipes. The safety valves of each exhaust gas heated economiser and each exhaust gas heated boiler which may be used as an economiser are to be provided with entirely separate waste steam pipes.

External drains and exhaust steam vents to atmosphere are not to be led to waste steam pipes.

It is recommended that a scale trap and means for cleaning be provided at the base of each waste steam pipe to the Surveyors' satisfaction.

Accumulation Tests

612 All safety valves are to be set under steam to a pressure not greater than 3 per cent above the approved design pressure of the boiler. During a test of 15 minutes with the stop valves closed and under full firing conditions the accumulation of pressure is not to exceed 10 per cent of the design pressure. During this test no more feed water should be supplied than is necessary to maintain a safe working water level.

Stop Valves

613 One main stop valve is to be fitted to each boiler secured direct to the shell. There are to be as few auxiliary stop valves as possible so as to avoid piercing the boiler shell more than is absolutely necessary. The arrangement, however, is to be such that where more than one boiler is fitted it is possible to supply the steam whistle, the steam steering gear, and the electric light machinery from at least two boilers.

Water Level Indicators

614 Every boiler is to be fitted with at least two independent means of indicating the water level in it, one of which is to be a glass gauge. The other means is to be either an additional glass gauge or an approved equivalent device.

On double-ended boilers, the above two water level indicators are to be fitted at each end, one indicator being positioned on each side.

On single-ended boilers, the water level indicators are also to be fitted one on each side of the boiler.

615 A set of not less than two test cocks will be accepted as the approved equivalent device mentioned in 614, for boilers having a design pressure less than 8,4 kg/cm² (120 lb/in²) or an internal diameter less than 1,83 m (6 ft).

The test cocks are to be fitted, where practicable direct to the boiler plating.

616 The water gauges are to be readily accessible and placed so that the water level is clearly visible.

The lowest visible part of the glass of the water gauge and the lower test cock, where test cocks are fitted, are to be situated at the lowest safe working water level.

- 617 The level of the highest part of the effective heating surfaces, e.g., combustion chamber top of a horizontal boiler and the furnace crown of a vertical boiler, is to be clearly marked in a position adjacent to the glass water gauge.
- 618 The cocks of all water gauges are to be accessible from positions free from danger in the event of the glass breaking.
- 619 If the water gauges are not fitted directly to the shell of the boiler but to stand pillars or columns, it is desirable that these pillars or columns should be bolted directly to the shell of the boiler. If they are connected to the boiler by means of pipes, the pipes are to be fitted with terminal cocks, not valves, secured direct to the boiler shell. For boilers exceeding 3 m (10 ft) in diameter the pillars are not to be less than 63 mm (2.5 in) and the connecting pipes not less than 38 mm (1.5 in) internal diameter. For boilers exceeding 2,3 m (7 ft 6 in) but not exceeding 3 m (10 ft) in diameter the pillars are not to be less than 50 mm (2 in) and the pipes not less than 32 mm (1.25 in) internal diameter, and for boilers 2,3 m (7 ft 6 in) in diameter and under, the pillars are not to be less than 45 mm (1.75 in) and the pipes not less than 25 mm (1 in) internal diameter. The upper ends of the connecting pipes are to be so arranged that there is no pocket or bend where an accumulation of water from the condensation of the steam can lodge. They should not pass through the uptake if they can be otherwise arranged. If, however, this condition cannot be complied with, they may pass through it by means of a passage at least 50 mm (2 in) clear of the pipe all round, open for ventilation.

Low Water Level Fuel Shut-Off and Alarm

620 Each oil fired boiler is to be fitted with a system of water level detection which is to be independent of any other mounting and which will operate audible and visible alarms and shut off automatically the oil supply to the burners when the water level falls to a predetermined low level.

Feed Check Valves

621 Two feed check valves, connected to separate feed lines, are to be provided for all main and auxiliary boilers which are required for essential services with the exception of boilers in which steam is generated exclusively by exhaust gas or steam, where one feed check valve will be accepted. See E 701.

The feed check valves are to be attached, wherever practicable, direct to the boiler but where the arrangements necessitate the use of standpipes between the boiler and the check valves, these pipes are to be of steel or other approved material.

For boiler feed water systems, see E 7.

Pressure Gauges

622 Each boiler is to be provided with a separate steam pressure gauge. Double-ended boilers are to be provided with a pressure gauge at each end. The gauges are to be placed where they are easily seen.

Blow-down and Scum Valves

623 Each boiler is to be fitted with at least one blow-down valve secured direct to the lower part of the boiler.

Where it is not practicable to attach the blow-down valve direct to water tube boilers, the valve may be placed immediately outside the boiler casing with a steel pipe of substantial thickness fitted between the boiler and valve. The pipe and valve are to be suitably supported and any pipe which may be exposed to direct heat from the furnace is to be adequately protected.

The blow-down valve and its connections to the sea need not be more than 38 mm (1.5 in) and is not to be less than 19 mm (0.75 in) in diameter. For cylindrical boilers the size of the valve in mm (in) may be generally 0,0085 times the diameter of the boiler in mm (in).

Vertical boilers are to be fitted with a blow-down valve or cock.

624 Blow-down valves and scum valves (where these latter are fitted) of two or more boilers may be connected to one common discharge, but where thus arranged there are to be screw-down non-return valves fitted for each boiler to prevent the possibility of the contents of one boiler passing to another.

For blow-down valve or cock on ship's side and attachments, see E 267 to E 270.

Salinometer Valve or Cock

625 Each boiler is to be provided with a salinometer valve or cock secured direct to the boiler in a convenient position. The valve or cock is not to be on the water gauge standpipe.

Hydraulic Tests

626 All boiler mountings are to be subjected to a hydraulic test of twice the design pressure with the exception of feed check valves which are to be tested to 2,5 times

the design pressure. The test pressures need not, however, be more than 70 kg/cm² (1000 lb/in²) above the design pressure.

MOUNTINGS AND FITTINGS FOR WATER TUBE BOILERS

General

627 Mountings and fittings not mentioned in 628 to 638 are to be in accordance with the requirements in 601 to 625.

Safety Valves

628 Water tube boilers are to be fitted with not less than two safety valves of area and design in general accordance with the requirements of 605 to 609, except that the minimum diameter of high discharge type valves may be 25 mm (1 in) or equivalent free area.

Each saturated steam drum and each superheater are to be provided with at least one safety valve.

Where the superheater forms an integral part of the boiler the relieving capacity of the superheater safety valve(s), based on the reduced pressure at the superheater outlet, may be included as part of the total relieving capacity required for the boiler. As some National Authorities limit the proportion of the superheater safety valve relieving capacity which may be credited towards the total capacity required for the boiler, builders should give attention to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

The boiler and superheater safety valves are to be so disposed and proportioned between saturated steam drum and superheater outlet that the superheater will be protected from overheating under all service conditions, including an emergency stop of the ship at full power.

Where it is proposed to fit full bore safety valves operated by independent pilot valves, the arrangements are to be submitted for consideration. The pipes connecting pilot valves and main valves are to be of ample bore and wall thickness to minimise the possibility of obstruction and damage.

Where it is impracticable to attach safety valves directly to the superheater the valves are to be located as near as possible thereto and fitted to a branch piece connected to the superheater outlet pipe.

In high temperature installations the drains from safety valves are to be led to a tank or other place where high temperature steam can be safely discharged.

Waste Steam Pipes

629 The waste steam pipe and passages leading to it from the safety valves are to be in general accordance with the requirements of 611.

In installations operating with a high degree of superheat, consideration is to be given to the high temperatures which waste steam pipes, silencers and surrounding spaces will attain when the superheater safety valves are blowing during accumulation tests and in service; adequate protection against heat effects is to be provided to the Surveyor's satisfaction. Waste steam pipes are to be led well clear of electric cables and any parts or structures sensitive to heat or likely to distort; the pipes are to be insulated where necessary. In these installations each boiler should have a separate waste steam pipe system to atmosphere with supporting and expansion arrangements such that no direct loading is imposed on the safety valve chests.

Safety Valve Settings

630 All boiler and superheater safety valves are to be set under steam to their respective working pressures which are to be not greater than 3 per cent above the approved design pressure of the boiler. In the setting of superheater safety valves, allowance is to be made for the pressure drop through the superheater so that under discharge conditions the pressure in the boiler will not exceed the approved boiler pressure.

In no case shall the superheater safety valve setting exceed by more than 3 per cent the pressure for which the steam piping and shafting are approved.

Accumulation Tests

631 Tests for accumulation of pressure are to be carried out with the stop valve closed and under full firing conditions for a period not exceeding seven minutes. The accumulation is not to exceed 10 per cent of the design pressure.

Where accumulation tests might endanger the superheaters, consideration will be given in cases of oil-fired boilers to the omission of these tests, provided that application is made when the boiler plan and sizes of safety valves are submitted for approval, and that the safety valves are of an approved type for which the capacity has been established by test in the presence of the Surveyors or an approved independent authority, or for which the Society is satisfied, by long experience of accumulation tests, that the capacity is adequate.

When it is agreed to waive accumulation tests it will be required that the valve makers provide a certificate for each safety valve, stating its rated capacity at the approved working conditions of the boilers and that the boiler makers provide a certificate for each boiler stating its maximum evaporation.

The safety valves are to be found satisfactory in operation under working conditions during the trials of the machinery on board ship.

Stop Valves

632 Where two or more boilers are connected together, stop valves of self-closing or non-return types are to be fitted.

Water Level Indicators

633 Every boiler is to be fitted with at least two independent means of indicating the water level in it, one of which is to be a glass water gauge.

The other means is to be either an additional glass water gauge or an approved equivalent device other than test cocks, but where a steam and water drum exceeding 3,96 m (13 ft) in length is fitted athwartships, two glass water gauges are to be fitted in suitable positions, one near each end of the drum.

634 The position of the glass water gauges of boilers in which the tubes are entirely drowned when cold is to be such that water is just showing in the glass when the water level in the steam drum is just above the top of the uppermost tubes when the boiler is cold. In boilers, the tubes of which are not entirely drowned when cold, the glass water gauges are to be placed, to the Surveyor's satisfaction, in the positions which have been found by experience to indicate satisfactorily that the water content is sufficient for safety when the boiler is worked under all service conditions.

Low Water Level Fuel Shut-Off and Alarm

635 Each oil fired boiler is to be fitted with two systems of water level detection which are to be independent of each other and of any other mounting on the boiler. Both systems are to operate audible and visible alarms and shut off automatically the oil supply to the burners when the water level falls to a predetermined low level.

Any proposal to depart from these requirements in the case of small auxiliary boilers would be the subject of special consideration.

Feed Check Valves and Water Level Regulators

636 Two feed check valves, connected to separate feed lines, are to be provided for each boiler and are to be attached, wherever practicable, direct to the boiler or to an economiser which forms an integral part of the boiler.

Where, however, the arrangements necessitate the use of a common inlet pipe on the economiser for both main and auxiliary feed systems, this pipe is to be as short as practicable and the arrangement of check valves is to be such that either feed line can be effectively isolated without interruption of the feed water supply to the boiler.

At least one of the feed water systems is to be fitted with an approved feed water regulator whereby the water level in the boilers is controlled automatically. (See E 7 for arrangements and details of boiler feed systems.)

637 The feed check valves are to be fitted with efficient gearing, whereby they can be satisfactorily worked from the stokehold floor, or other convenient position.

638 Standpipes on boilers, for feed inlets, are to be designed with an internal pipe to prevent direct contact between the feed pipe and the boiler shell or end plates with the object of minimizing thermal stresses in these plates.

Similar arrangements are to be provided for desuperheater and other connections where significant temperature differences occur in service.

Hydraulic Tests

639 All boiler mountings are to be subjected to a hydraulic test of twice the approved boiler design pressure with the exception of feed check valves and other mountings connected to the main feed system which are to be tested to 2,5 times the approved boiler design pressure, or twice the maximum pressure which can be developed in the feed line in normal service, whichever is the greater.

MOUNTINGS AND FITTINGS FOR UNFIRED PRESSURE VESSELS

General

640 Each receiver which can be isolated from a safety valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C (300°F). See also F 310.

Where carbon dioxide gas is used for fire extinguishing, it is recommended that the discharge from the fusible plug be piped to deck.

641 Each receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

Cross-references

642 For starting air pipe systems and safety fittings, see H 612.

For mountings for liquefied petroleum gas vessels, see E 12.

Section 7

PRESSURE VESSELS FOR THE CARRIAGE OF LIQUEFIED PETROLEUM GASES

General

701 The requirements of this Section are applicable to welded steel pressure vessels of cylindrical or spherical form intended for the carriage of liquefied petroleum gas under pressure at ambient or lower temperatures. The vessels should be constructed generally in accordance with the Rules for Welded Pressure Vessels Class 1 and installed in closed holds with the vessels and their mountings protruding above the weather deck. See 704.

See E 12 for requirements for filling, discharging, venting and inerting pipe arrangements, tank connections and mountings, cargo pumps and compressors and other associated equipment.

See D 70, D 71 and D 72 for ship requirements for the carriage of liquefied gases.

Plans

702 Before construction of the vessels is commenced the following particulars where applicable and plans are to be submitted for approval:—

- (1) Nature of cargoes, together with maximum vapour pressure and minimum liquid temperature for which the pressure vessels are to be approved, and proposed hydraulic test pressure.
- (2) Particulars of materials proposed for the construction of the vessels, see 703.
- (3) Particulars of refrigeration equipment.
- (4) General arrangement plan showing location of pressure vessels in the ship.
- (5) Plans of pressure vessels showing attachments, openings, dimensions, details of welded joints and particulars of proposed stress relief heat treatment.
- (6) Plans of seatings, securing arrangements and deck sealing arrangements.
- (7) Plans showing arrangement of mountings, level gauges and number, type and size of safety valves.

Materials

703 Plate materials are to be manufactured and tested in accordance with the requirements of Q 3 and the specification of the material is to be submitted for approval as required by Q 301 for steels operating at low metal tempera-

tures. In addition to the tensile and bend test requirements the tests of plates at the steel works are to include Charpy V-notch impact tests at the design metal temperature.

For pressure vessels where the carrying temperature is 0°C (32°F) or less, specifications of the weld metal as well as the plate material, including Charpy V-notch impact properties at the carrying temperatures, are to be submitted for approval. For pressure vessels where the cargo is carried at atmospheric temperature the plate material is to have minimum impact properties of 4,84 kg m (35 ft lb) at 0°C (32°F). For details of impact tests see Q 208. Tests to determine the impact strength of the weld metal should have regard to variations in welding positions

Design

704 For pressure vessels where the cargo is carried at atmospheric temperature, the vapour pressure used for design purposes is not to be less than the vapour pressure of liquefied gas at 45°C (113°F).

The thickness at any part of the pressure vessel is not to be less than determined by the formula in J 201, J 208 and J 209, as applicable, for a design pressure appropriate to the vapour pressure and static liquid head. The thickness so obtained is to be increased where necessary to take account of the following:—

- (a) local stresses in shell and ends due to reactions from seatings and securing fitments when the ship is upright or listed up to 30°,
- (b) thermal expansion and contraction effects where the liquid cargo is to be carried at temperatures below ambient,
- (c) dynamic loading from rolling, pitching and heaving of the ship in a seaway to the extent given in D 7116. Alternatively, provision for dynamic loading can be made by assuming that pressures due to static head are doubled.

Special attention is to be given to the design of attachments welded to the pressure vessel for supporting or securing purposes so as to minimize stress concentrations at these points.

Seatings are to be so designed as to ensure adequate and uniform support to the pressure vessel having due regard to deflections of the hull structure in a seaway.

All valves, fittings and manholes are to be located on that portion of the pressure vessel which protrudes above the weather deck, and are to be protected from damage and corrosion. Manholes should be placed above the liquid level. Valves and fittings are to be of steel or other approved ductile material. The sealing arrangements at deck are to provide for expansion and contraction of the vessel under normal operating pressure and temperature and are to be watertight.

Suitable arrangements are to be made to prevent the pressure, temperature and liquid level of tanks from rising above safe limits, and details are to be submitted. It should also be stated whether the safety arrangements are controlled by statutory requirements of any National Authority.

Refrigeration Equipment

705 Where refrigeration equipment is installed, two or more refrigerating units are to be provided of capacity sufficient to maintain the liquid cargo at the carrying temperature with any one unit out of use. See E 1228.

Construction and Tests

706 In general, pressure vessels are, so far as practicable, to be constructed and tested to the Rules for Class 1 Welded Pressure Vessels, except that the work may be carried out by manufacturers not appearing on the Society's Class 1 List, provided fabrication and tests are completed to the satisfaction of the Surveyors.

Some relaxation of Class 1 requirements as regards tests and heat treatment may be permitted, dependent on design, scantlings and material of the vessel, but generally, welded joints should be subjected to radiographic examination. Where the pressure vessels are too large for furnace stress relief, proposals for local stress relief and stress relief of prefabricated components will be considered.

Where plates are hot formed to shape, check tests including impact tests are to be made on the material. Where a large number of plates are involved, check tests on selected plates will suffice, provided the Surveyor is satisfied that the hot forming process is closely controlled.

For pressure vessels where the operating metal temperature is 0°C (32°F) or less, the weld metal Charpy V-notch impact test specimens are to be prepared as stated in J 419. The impact tests are to be made at the carrying temperature for which the vessel is approved and the test results are to comply with approved specification. See 703.

Hydraulic Tests

707 The pressure vessel is to be tested as required by J 445. The static head of the water may be included in the test pressure if the amount is significant.

On completion, the vessels are to be clearly marked with the maximum vapour pressure and minimum carrying temperature.

Section 8

RIVETED PRESSURE VESSELS

NOTE.—The use of fusion welded construction has almost entirely replaced riveted construction for new fired and unfired pressure vessels. Similarly, the staying of flat surfaces by welded attachment of the stays has to a great extent replaced screwed, nutted and riveted forms of stay attachment. Nevertheless, in the event of riveted construction and screwed, nutted and riveted forms of stay attachments being used for new pressure vessels or in the repair of existing pressure vessels, the following Rules are applicable. These Rules, though presented in a different form, embody the requirements of the Society's previous Rules for riveted pressure vessels.

General

- 801 All steel plates which are welded, dished, flanged or locally heated are to be afterwards efficiently heat treated.
- 802 Butt straps are to be cut from plates and not from rolled strips.
- 803 All rivet holes are to be drilled, and as far as possible they are to be drilled in place. After drilling the plate the burrs are to be removed and the faying surfaces of the plates cleaned, and the sharp outer edges of holes also removed.
- 804 Steel stays are not to be welded. If plus threads are desired, the ends of the stay bars may be upset or the bars may be drawn down in the central portions from bars originally of the size of the ends. In either of these two cases the bars are to be subsequently annealed throughout. In double-ended boilers the through longitudinal stays are to be supported at or near the middle of their length.
- 805 Screw stays of combustion chambers where fitted with nuts are to be, so far as possible, normal to the chamber plates. Where this is not possible they are to be fitted with taper washers to provide a fair bed for the nuts.
- 806 Nuts to screw stays in combustion chambers are not to be less than 19 mm (0.75 in) thick for stays up to 38 mm (1.5 in) diameter over threads, 22 mm (0.875 in) thick for 41 and 45 mm (1.625 and 1.75 in) stays, 25 mm (1 in) thick for 48 and 51 mm (1.875 and 2 in) stays, and 29 mm (1.125 in) thick for stays over 51 mm (2 in) in diameter. The nuts are to be made of solid mild steel or of iron which is to be without weld. The nuts for longitudinal stays are to be appropriate to the diameters of the stays, the outside nuts having the thickness provided for ordinary nuts, and the inside nuts having the thickness provided for lock nuts.

807 Screw stays 32 mm (1·25 in) in diameter and above should have 9 threads per 25,4 mm (1 in), and all stays 51 mm (2 in) in diameter and above passing through plates, and secured by nuts on each side of the plate, should have not more than 6 threads per 25,4 mm (1 in).

808 Where jointed longitudinal stays are fitted between the front and back tube plates they are to be fitted with pins having an effective sectional area not less than 25 per cent in excess of that of the stay. The pins may be slack in the holes, the total slackness being not more than 1,5 mm (0.0625 in). The pins are to be as close as possible to the shoulder of the eye forging. The shoulder of the forging is to have a diameter not less than 25 mm (1 in) greater than the diameter of the hole.

809 The end plates in the steam space in way of uptakes are to be shielded from contact with the heated gases.

Cross-reference

810 For requirements as to smoke box doors and the omission of dampers in oil-fired boilers, see E 332 and E 333.

CYLINDRICAL SHELLS SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

811 The minimum thickness, T, of a cylindrical shell is to be determined by the following formula:—

$$T = \frac{PD}{52,2 R_{20} J} + 1,6 mm$$

$$\left({\rm T} = \frac{{\rm PD}}{{\rm 1162\,R_{20}\,J}} + 0.06\,{\rm in} \right)$$

where T is as stated above, in mm (in),

P = design pressure, in kg/cm² (lb/in²)

R₂₀ = specified minimum tensile strength of plate, in kg/mm² (ton/in²),

J = strength of the longitudinal seams, with double butt straps, calculated by the methods described in 812—expressed as a fraction,

D = inside diameter of the outer strake of plating of the cylindrical shell, in mm (in).

Joint Strength

812 The strength of a riveted joint, J, is found from the following formulæ, the first two being applicable to any type of joint, and the third to that type of joint in which the number of rivets in the inner rows is double that in the outer row. The lowest value given by the application of these formulæ is to be taken as the strength of the joint.

Strength of plate at joint as compared with solid plate
$$= \frac{p - d}{p}$$
 (1)

Strength of rivets as compared with solid plate
$$= \frac{S \text{ a n C}}{R_{20} \text{ p T}}$$
 (2)

Combined strength of the plate at the inner row of rivet holes and of the rivets in the outer row

$$= \frac{p - 2d}{p} + \frac{SaC}{R_{20}pT}$$
 (3)

where p = pitch of rivets at outer rows, in mm (in),

d = diameter of rivet holes, in mm (in),

a = sectional area of one rivet, in mm² (in²),

n = number of rivets which are fitted in the pitch p,

T = thickness of plate, in mm (in),

R₂₀ = specified minimum tensile strength of plates, in kg/mm² (ton/in²),

S = shearing strength of rivets, which is taken generally to be 36 kg/mm² (23 ton/in²), and may be 0,85 of the minimum tensile strength of the rivet bars,

C = 1,0 for rivets in single shear as in lap circumferential joints, 1,875 for rivets in double shear as in double butt-strapped longitudinal joints.

813 All longitudinal seams are to be butt jointed with double butt straps; the outer butt strap is to be at least 0,625 of the strength of the plate and of sufficient thickness to permit of efficient caulking at its outer edges. The inner butt strap is to be 3 mm (0.125 in) thicker than the outer butt strap.

In cases where the number of rivets in the inner rows is double the number in the outer row, the minimum thickness of the outer butt strap T_O, in mm (in) is to be:—

$$T_{o} = \frac{0.625 (p - d) T}{(p - 2d)}$$
 (1)

and the minimum thickness of the inner strap T_j, in mm (in), is to be:—

$$T_i = \frac{0.625 (p - d) T}{(p - 2d)} + 3 mm$$
 (2)

$$\left(T_{i} = \frac{0.625 (p - d) T}{(p - 2d)} + 0.125 in\right)$$

Spacing of Rivets

814 In all cases the clear space between a rivet hole and the edge of a plate is not to be less than the diameter of the rivet holes, i.e., the centre of the rivet hole is to be at least 1,5 diameters from the edge of the plate.

In joints whether lapped or fitted with butt straps, in which there are more than one row of rivets and in which there is an equal number of rivets in each row, the distance between the rows of rivets is not to be less than 0,33 p + 0,67 d with zigzag riveting, or 2 d with chain riveting.

In joints in which the number of rivets in the outer rows is one-half of the number in each of the inner rows, and in which the inner rows are chain riveted, the distance between the outer rows and the next rows is not to be less than $0.33~\mathrm{p} + 0.67~\mathrm{d}$ or $2~\mathrm{d}$, whichever is the greater, and the distance between the rows in which there are the full number of rivets is not to be less than $2~\mathrm{d}$.

In joints in which the number of rivets in the outer rows is one-half of the number in each of the inner rows and in which the inner rows are zigzag, the distance between the outer rows and the next rows is not to be less than 0.2 p + 1.15 d, and the distance between the rows in which there are the full number of rivets is not to be less than 0.165 p + 0.67 d.

In the above, p is the pitch of the rivets in the outer rows.

815 In longitudinal seams, with double butt straps, the maximum pitch of the rivets is not to be greater than:—

$$C T + 40 mm$$
 ($C T + 1.625 in$)

where T is the thickness of the plate, in mm (in), and C is a coefficient as given in Table J 8.1.

TABLE J 8.1

Number of Rivets per Pitch	Coefficient C
1	1,75
2	3,50
3	4,63
4	5,52
5	6,00

Circumferential Seams

816 The strength of the seams joining the end plates to the cylindrical shell is not to be less than 0.42 of that of the solid shell plate. Where the shell plates exceed 16 mm (0.625 in) in thickness the seams connecting the shell plates to the end plates are to be at least double riveted. Where the shell plates exceed 13 mm (0.5 in) in thickness the intermediate circumferential seams of double-ended boilers are to be at least double riveted.

817 The circumferential seam at or near the middle of the length of single-ended boilers is to have a strength of joint not less than 0,6 of the solid plate. The inner circumferential seams of double-ended boilers are to have a strength of joint not less than 0,62 of the solid plate. In any case there are to be at least three rows of rivets where single-ended boilers have shell plates over 35 mm (1·375 in) in thickness and where double-ended boilers have shell plates over 30 mm (1·1875 in) in thickness.

818 The circumferential seams of the shells of vertical boilers are to have a strength of not less than 0,42 of the solid plate. Where these seams are not complete circles, and where the shell plates exceed 16 mm (0.625 in) in thickness, the riveting is to be at least double.

Strength of Cylindrical Shells in way of Stays and Openings

819 Where more than three screw stays pierce the cylindrical shell in a horizontal line, if d is their diameter and p the pitch, $\frac{p-d}{p}$ should be not less than the strength required for the shell longitudinal joints. To meet this requirement it may be necessary for the stays to be arranged out of line with one another longitudinally.

820 If holes are cut in cylindrical shells for manholes, sight holes or for fixing of mountings, the diameters of the holes being greater than 2,5 times the thickness of the shell plating plus 70 mm (2.75 in), compensation is to be provided such that the strength in way of the holes is not less than that required for the longitudinal joint.

HEMISPHERICAL ENDS SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

821 The minimum thickness, T, of a hemispherical end without stays or other supports and made from more than one plate is to be determined by the following formula:—

$$T = \frac{PR_i}{CR_{20}J} + 1,6 \, mm \, \left(T = \frac{PR_i}{CR_{20}J} + 0.06 \, in\right)$$

where T is as stated above, in mm (in),

P = design pressure, in kg/cm² (lb/in²),

 $R_{20} = \text{specified minimum tensile strength of plate, in } kg/mm^2 (ton/in^2),$

J = strength of riveted joint as a fraction of the solid plate,

R_i = inner radius of curvature, in mm (in),

C = 50,6 (1130) for treble riveted, 49,4 (1100) for double riveted, 43,3 (970) for single riveted. FLAT PLATES SUPPORTED BY STAYS SECURED IN VARIOUS WAYS OTHER THAN WELDING

Note.—If steel of a tensile strength less than 41 kg/mm² (26 ton/in²) is used for flat plates, then the design pressure calculated by the following formulæ for a given plate thickness would require to be correspondingly reduced.

Minimum Thickness

822 The minimum thickness, T, of flat plates supported by stays is to be determined by the following formula:—

$$T = d\sqrt{\frac{P}{C}} + 0.8 \text{ mm} \quad \left(T = d\sqrt{\frac{P}{C}} + 0.03125 \text{ in}\right)$$
 (1)

In this formula and in the formulæ in 824

T is as stated above, in mm (in),

P = design pressure, in kg/cm² (lb/in²),

T_w = thickness, in mm (in), of the washers, strips, or doublings employed,

 $d = \sqrt{A^2 + B^2}$ where the stays are regularly pitched,

A being the horizontal pitch of the stays, in mm (in), and

B the vertical pitch of the stays, in mm (in).

Where the stavs are irregularly pitched, then

- d = diameter of the largest circle which can be drawn through three points of support without enclosing another point of support. Only two points of support may be on one side of any diameter of the circle. Where a flange is taken as a point of support, the circumference of the circle is to be tangent to the line of curvature,
- C = a constant, depending on the method of support as detailed below. Where various forms of support are used the constant C is to be the mean of the values for the respective methods adopted.

Where stays are screwed into the plate and their ends are riveted over, then:—

for plates not exposed to flame C = 4100 (C = 58350), for plates exposed to flame C = 3600 (C = 51200).

In these cases the thickness of the plate is to be at least half the diameter of the stay required by the Rules. Where stays are screwed into the plate and fitted with nuts on the outside, then:—

for plates not exposed to flame C = 6200 (C = 88050). for plates exposed to flame C = 5400 (C = 76800).

Where stays pass through the plate and are fitted with nuts inside and outside, then:—

for plates not exposed to flame C = 6900 (C = 98300), for plates exposed to flame C = 6050 (C = 86000).

Where plates are stiffened by flanging, the outer radius of which is not greater than 3,5 times the thickness of the plate, then:—

for plates not exposed to flame C = 7900 (C = 112800), for plates exposed to flame C = 6900 (C = 98300).

Where stay tubes are screwed into tube plates, and expanded, then:—

for stay tubes fitted with nuts C = 5180 (C = 73700), for stay tubes not fitted with

nuts C = 3740 (C = 53250).

Where a flat plate has a manhole or sight hole and the opening is strengthened by flanging, the total depth, H, of the flange, measured from the outer surface of the plate is not to be less than:—

$$H = \sqrt{T W}$$
 (2)

where H = depth of flange, in mm (in),

T = thickness of the plate, in mm (in),

W = minor axis of the manhole or sight hole, in mm (in).

823 For the tops and sides of combustion chambers the distance between the rows of stays nearest to the back tube plate or the back plate respectively and the commencement of curvature of these plates at their flanges is not to be greater than the distance apart of the rows of stays, in mm (in).

The stays of the combustion chambers are to be so placed that the seams of the plates can be caulked without removing the stay nuts.

For the tops of combustion chambers where they are joined to the sides by curved portions, if the outer radius of the curved portion is less than half the allowable distance between the girders, the distance between the first girder and the inner surface of the side plate is not to exceed the allowable distance between the girders. If the radius of the curved portion is greater than half the allowable distance between the girders, the width of the flat portion measured from the centre of the girder is not to be more than half the allowable distance between the girders.

- 824 Where the plate is strengthened by washers, stiffening strips or doubling plates having a thickness, $T_{\rm w}$, at least two-thirds of that of the plate but not greater than that of the plate, then the minimum thickness, $T_{\rm s}$, of the plate is to be determined as follows:—
 - (a) Where stays pass through the plate and are fitted with nuts inside and washers and nuts outside, the diameter of the washers being at least 3,5 times that of the stay,

$$T = \sqrt{\frac{P d^2}{7200}} - 0.15 T_W^2 + 0.8 mm$$

$$\left(T = \sqrt{\frac{P d^2}{102400}} - 0.15 T_W^2 + 0.031 25 in\right)$$
(1)

(b) Where the stays, nuts and washers are fitted as in (a), the diameter of the washers being at least two-thirds of the pitch of the stays and riveted to the plate in an efficient manner,

$$T = \sqrt{\frac{P d^2}{7200} - 0.35 T_W^2 + 0.8 mm}$$

$$\left(T = \sqrt{\frac{P d^2}{102400} - 0.35 T_W^2 + 0.03125 in}\right)$$
(2)

(c) Where the plate is stiffened by strips at least twothirds of the pitch of the stays in breadth and riveted to the plate in an efficient manner,

$$T = \sqrt{\frac{P d^2}{7200}} = 0,55 T_W^2 + 0,8 \text{ mm}$$

$$\left(T = \sqrt{\frac{P d^2}{102400}} - 0.55 T_W^2 + 0.03125 \text{ in}\right)$$
(3)

(d) Where the plate is fitted with doubling plates which are riveted to the plate in an efficient

$$T = \sqrt{\frac{P d^2}{7200} - 0.85 T_W^2 + 0.8 mm}$$

$$\left(T = \sqrt{\frac{P d^2}{102400} - 0.85 T_W^2 + 0.03125 in}\right)$$
(4)

825 (a) For the portions of tube plates in the nests of tubes the minimum thickness, T, of the tube plate is to be determined as follows:—

$$T = p_{m} \sqrt{\frac{P}{C}} + 0.8 \text{ mm}$$

$$\left(T = p_{m} \sqrt{\frac{P}{C}} + 0.03125 \text{ in}\right)$$
(1)

where T is as stated above, in mm (in),

P = design pressure, in kg/cm² (lb/in²),

p_m = mean pitch, in mm (in), of the stay tubes supporting any portions of the plate (being the sum of the four sides of the quadrilateral divided by 4),

C = 3530 (C = 50 200) where the stay tubes are screwed and expanded into the plate and nuts are fitted (see J 250),

C = 2740 (C = 38 900) where the stay tubes are screwed and expanded into the plate and nuts are not fitted.

(b) For the wide water spaces of front tube plates between the nests of tubes and between the wing rows of tubes and the shell the minimum thickness, T, of the front tube plate is to be determined as follows:—

$$T = \sqrt{\frac{P d^2}{C} - 0.55 T_W^2} + 0.8 \text{ mm}$$

$$\left(T = \sqrt{\frac{P d^2}{C} - 0.55 T_W^2} + 0.03125 \text{ in}\right)$$
(2)

where T is as stated above, in mm (in),

P = design pressure, in kg/cm² (lb/in²),

 T_W = thickness of the doubling plate, where so fitted, in mm (in),

 $d^2 = A^2 + B^2,$

A = horizontal pitch of stay tubes, in mm (in), measured across the wide water space,

B = vertical pitch of stay tubes in the bounding rows, in mm (in),

C = 5180 (C = 73 700) where the stay tubes are screwed and expanded into the tube plate and nuts are fitted to each stay tube,

C = 4540 (C = 64 500) where the stay tubes are screwed and expanded into the tube plate and nuts are fitted only to alternate stay tubes,

C = 3740 (C = 53 250) where the stay tubes are screwed and expanded into the tube plate and nuts are not fitted.

Combustion Chamber Girders

826 For plate girders supporting the tops of combustion chambers by means of stays, the following formula is to be used:—

$${\rm T} = \frac{{\rm P}\,{\rm D}\,{\rm L}\,({\rm L}-{\rm p})}{{\rm C}\,{\rm d}^2}\,\frac{44}{{\rm R}_{20}} \qquad \left({\rm T} = \frac{{\rm P}\,{\rm D}\,{\rm L}\,({\rm L}-{\rm p})}{{\rm C}\,{\rm d}^2}\,\frac{28}{{\rm R}_{20}}\right)$$

where T = thickness of girder at centre, or the sum of the thicknesses of the plates where the girder is made of two plates, in mm (in),

P = design pressure, in kg/cm² (lb/in²),

d = depth of girder at centre, in mm (in),

L = length of girder, in mm (in), measured between the tube plate and back chamber plate inside, or between tube plates in chambers common to two opposite furnaces,

p = pitch of stays supported by the girder, in mm (in),

D = distance apart of the girders, centre to centre, in mm (in),

 $R_{20} = minimum$ specified tensile strength of the material forming the girder, in kg/mm² (lb/in²),

$$C = \frac{n}{n+1} \quad 1100$$

$$\left(C = \frac{n}{n+1} \quad 15840\right)$$
where the number of stays n in each girder is odd,

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$$C = \frac{n+1}{n+2} \quad 1100$$

$$\left(C = \frac{n+1}{n+2} \quad 15 \quad 840\right)$$
where the number of stays n in each girder is even.

Hydraulic Test

827 In all new boilers having design pressures up to 7 kg/cm² (100 lb/in²) the hydraulic test pressure is to be twice the design pressure. For boilers with design pressures greater than 7 kg/cm² (100 lb/in²) the hydraulic test pressure is to be 1,5 times the design pressure plus 3,5 kg/cm² (50 lb/in²).

In air receivers having design pressures up to 21 kg/cm² (300 lb/in²) the hydraulic test pressure is to be 1,5 times the design pressure, plus 3,5 kg/cm² (50 lb/in²). Where higher design pressures are used, the test pressure need not be more than 14 kg/cm² (200 lb/in²) above the design pressure.

Cross-references

828 The design of pressure parts, not mentioned in this Section, is to be in accordance with J 2 where applicable.

Access arrangements are to be in accordance with J 301 to J 307 where applicable.

APPENDIX

FIRMS RECOGNIZED BY THE COMMITTEE FOR THE MANUFACTURE OF CLASS 1
FUSION WELDED PRESSURE VESSELS AS AT 29.10.71

Note: The Society's Office giving attendance at the Works is shown in brackets.

United Kingdom

Adamson & Hatchett, Ltd., Dukinfield, Cheshire.

(MANCHESTER)

Adamson, Joseph & Co., Ltd., Hyde, Cheshire.

(MANCHESTER)

Aiton & Co., Ltd., Derby. (NOTTINGHAM)

Babcock & Wilcox (Operations), Ltd., Renfrew. (Glasgow)

Babcock Package Boilers, BDP Group (A division of Babcock & Wilcox (Operations) Ltd.), Renfrew. (Glasgow)

Balfour, Henry & Co., Ltd., Leven, Fife. (LEITH)

Brown, John, Engineering (Clydebank) Ltd., Clydebank. (Glasgow)

Butterfield, W. P. (Engineers) Ltd., P.O. Box No. 38, Shipley, Yorks. (LEEDS)

Cammell Laird & Co. (Shipbuilders & Engineers) Ltd., Birkenhead. (LIVERPOOL)

Clark, George, & N.E.M., Ltd., Hartlepool Works.

(MIDDLESBROUGH)
Clarke Chapman-John Thompson Ltd., Annan. (Glasgow)
Clarke Chapman-John Thompson Ltd., Gateshead.

(Newcastle)

Clarke Chapman-John Thompson Ltd., Horsley Piggott Division, Windmill Works, Dudley, Worcs. (BIRMINGHAM)

Clarke Chapman-John Thompson Ltd., Power Plant Division, Ettingshall, Wolverhampton. (BIRMINGHAM)

Clayton, Son & Co., Ltd., Pepper Road Works and Moor End Works, Hunslet, Leeds. (LEEDS)

Danks, Edwin & Co. (Oldbury) Ltd., (BIRMINGHAM)

Danks of Netherton, Ltd., Netherton. (BIRMINGHAM)

Distington Engineering Co., Workington, Cumberland. (Barrow)

English Electric Co., Ltd., Stafford. (BIRMINGHAM)

Foster Wheeler John Brown Boilers Ltd., Brenda Road Works, Hartlepool. (MIDDLESBROUGH)

Foster, Yates & Thom, Ltd., Canal Works, Blackburn.
(Manchester)

Grazebrook, M. & W., Ltd., Dudley, Worcestershire.

(BIRMINGHAM)

Harland & Wolff, Ltd., Belfast. (BELFAST)

Head Wrightson Teesdale, Ltd., Thornaby-on-Tees.
(MIDDLESBROUGH)

Horseley Bridge & Thomas Piggott, Horseley Piggott Division of Clarke Chapman-John Thompson Ltd., P.O. Box 5, Horseley Works, Tipton, Staffs. (BIRMINGHAM)

Hoval-Farrar Boilers, Ltd., Newark. (Nottingham)

International Combustion, Ltd., Derby. (Nottingham)

Jenkins, Robert & Co., Ltd., Rotherham. (Sheffield)

Marshall & Anderson, Ltd., Manse Road, Motherwell. (Broomside Works). (Glasgow)

Marshall, Sons & Co., Ltd., Britannia Works, Gainsborough. (Sheffield)

Millspaugh, Ltd., Sheffield. (SHEFFIELD)

Motherwell Bridge Engineering, Ltd., (Motherwell Stephen Ltd.,) Motherwell. (Glasgow)

Neill, Wm., & Son (St. Helens), Ltd., Bold, St. Helens. (Liverpool)

Newton Chambers Engineering, Ltd., Thorncliffe, Nr. Sheffield. (Sheffield)

Old Park Engineering Ltd., Dudley, Worcestershire.

(BIRMINGHAM)

Penman & Co., Ltd., (BDP Group), Glasgow. (Glasgow) Robey of Lincoln, Ltd., Globe Works, Lincoln.

(NOTTINGHAM)

Stephen, Alexander, Engineering, Ltd., (Motherwell Stephen Ltd.), Glasgow. (Glasgow)

Thompson, John, Cochran Ltd., P.O. Box 33, Lincoln.
(Nottingham)

Towler & Son, Ltd., London, E.15. (LONDON)

Vickers Ltd., Barrow Engineering Works, Barrow-in-Furness. (Barrow)

Watson, Robert & Co. (Constructional Engineers) Ltd., Bolton, Lancs. (Manchester)

Weir Pumps Ltd., Cathcart, Glasgow. (Glasgow)

Whessoe, Ltd., Darlington. (MIDDLESBROUGH)

Whessoe (Stockton Works), Ltd., Stockton-on-Tees.

(MIDDLESBROUGH)

Yarrow & Co., Ltd., Scotstoun, Glasgow. (Glasgow)

Australia

Babcock & Wilcox Australia, Ltd., Regents Park, N.S.W. (Sydney)

Bernard-Smith P.D.M. Pty., Ltd., Sydney. (SYDNEY)

Industrial Engineering, Ltd., Steelweld Fabrications Division, Braybrook, Victoria. (Melbourne)

Perry Engineering Co., Ltd., Adelaide, S. Australia.

(ADELAIDE)

Thompsons (Castlemaine) Ltd., Melbourne, Victoria.

(MELBOURNE)

Vickers Hoskins Pty. Ltd., Bassendean, Western Australia. (Fremantle)

Austria

Vereinigte Osterreichische Eisen-und-Stahlwerke AG., Linz an der Donau. (VIENNA) Waagner-Biro AG., Graz, Styria. (VIENNA)

Belgium

S.A. Cockerill-Ougree-Providence, Seraing. (ANTWERP)

Brazil

Cia. Brasileira de Caldeiras (CBC), Varginha, Minas Gerais (SAO PAULO)

Canada

Babcock & Wilcox Canada, Ltd., Galt, Ontario.

(TORONTO)

Canadian Vickers Industries, Ltd., Montreal. (Montreal)
Davie Shipbuilding, Ltd., Lauzon, P.Q. (Quebec)
Dominion Bridge Co., Ltd., Lachine, P.Q. (Quebec)
Foster Wheeler, Ltd., St. Catherines, Ontario. (Toronto)

Denmark

Aalborg Vaerft A/S, Aalborg. (Aalborg)

Finland

Valmet Oy, Rautpohjan tehdas, Jyvaskyla.

(HELSINGFORS)

Oy Wärtsilä A/B, Helsinki Works, Helsingfors.

(HELSINGFORS)

France

Ateliers & Chantiers de Bretagne, Nantes. (Nantes) Babcock Atlantique, St. Nazaire. (Nantes)

Germany

Deutsche Babcock & Wilcox Dampfkesselwerke A.G., Oberhausen. (Dusseldorf)

Blohm & Voss A.G., Hamburg. (Hamburg)

Borsig A.G., Berlin-Tegel. (BERLIN)

Bremer-Vulkan, Schiffbau & Maschinenfabrik, Bremen-Vegesack. (Bremen)

Dinglewerke A.G., Zweibruecken, Werke in Zweibruecken und Bierbach-Saar. (Saarbrucken-Saar)

Gutehoffnungshutte Sterkrade A.G., Werk Sterkrade, Oberhausen-Sterkrade. (Dusseldorf)

Howaldtswerke-Deutsche Werft A.G., Hamburg und Kiel, Werk Kiel. (Kiel)

Klockner-Werke A.G., Georgsmarienwerke, Osnabruck, Werk Georgsmarienhutte. (Hannover)

Koerver & Lersch, Krefeld. (Dusseldorf)

Krupp, Fried., Industriebau und Maschinenfabrieken Essen Apparatebau, Essen. (Dusseldorf)

Mannesmannrohren Werke G.m.b.H., Duisburg-Huckingen.
(Dusseldorf)

Mannesmannrohren Werke GmbH, Mulheim.

(Dusseldorf)

Maschinenfabrik Augsburg-Nurnberg A.G., Augsburg.
(Augsburg)

Maschinenfabrik Augsburg-Nurnberg A.G., Gustavsburg.
(Mannheim)

Maschinenfabrik Augsburg-Nurnberg A.G., Werk Hamburg, Hachmannkai, Hamburg. (HAMBURG)

Rheinstahl Hüttenwerke A.G., Werk Ruhrstahl Henrichshuette, Hattingen-Ruhr. (DORTMUND)

Rheinstahl Transporttechnik Formteile Ruhrstahl Brackwede, of Brackwede (Westf.) (Hannover)

Stahl-und-Rohrenwerke Reischolz G.m.b.H., Dusseldorf-Reisholz: (Dusseldorf)

Steinmuller, L. & C., G.m.b.H., Gummersbach/Rhld.

(KOLN)

Weser A.G., Bremen. (BREMEN)

Holland

"Breda" N.V. Machinefabrik, v/h Backer & Rueb, Rotterdam. (ROTTERDAM)

Bronswerk Apfa-Apparatenfabriek Utrecht N.V., Utrecht.
(Amsterdam)

Bronswerk-Feyenoord Afd. AMAF N.V. (AMSTERDAM)

Dok-en Werf-Maatschappij Wilton-Fijenoord N.V., Schiedam. (ROTTERDAM)

Kon. Mij. "De Schelde" N.V., Vlissengen. (ROTTERDAM)

Nederlandsche Dok en Scheepsbouw Mij. (Amsterdam) Nederlandsche Electrolasch N.V., Leiden. (Rotterdam) Rotterdamsche Droogdok Maatschappij N.V., Rotterdam. (Rotterdam)

Stork, Gebr. & Co., N.V., Hengelo. (AMSTERDAM)

India

ACC-Vickers-Babcock Ltd., Durgapur. (CALCUTTA)
Indian Sugar & General Engineering Corporation, Yamunanagar. (YAMUNANAGAR)

Italy

Acciaieria & Tubificio di Brescia, Brescia. (Brescia) Ansaldo Meccanico Nucleare S.p.A., Stabilimento Meccanico, Genoa. (Genoa)

Belleli R., Mantova. (Brescia)

Bonaldi D. & Co., S.p.A., Crema. (MILAN)

Bosco, A., Officine Meccaniche e Fonderie, Terni. (Naples) C.I.P.I. S.p.A., Venice, (also known as Guido Sartori S.p.A.) (Venice)

Costruzioni Meccaniche Industriali Genovesi-C.M.I., S.p.A., Genoa-Fegino. (Genoa)

Franco Tosi, S.p.A., Legnano. (MILAN)

Nuovo Pignone, Industrie Meccaniche e Fonderia S.p.A., Stabilimento di Massa, Apuania. (La Spezia)

Terni, Societa per l'Industria e l'Elettricita, Terni. (NAPLES)

Japan

Babcock-Hitachi K.K., Kure Works, Kure. (Нікозніма) Babcock-Hitachi K.K., Yokohama. (Уоконама)

Chiyoda Chemical Engineering & Construction Co., Ltd., Kawasaki Factory, Kawasaki. (Yоконама)

Fuji Electric Co., Ltd., Kawasaki Factory, Kawasaki. (Yоконама)

Hirano Iron Works Co., Ltd., Osaka. (Kobe)

Hitachi Shipbuilding & Eng. Co., Ltd., Innoshima Shipyard, Innoshima. (Kobe)

Hitachi Shipbuilding & Eng. Co., Ltd., Maizuru Shipyard, Maizuru. (Kobe)

Hitachi Shipbuilding & Eng. Co., Ltd., Sakurajima Works, Osaka. (Kobe)

Ishikawajima-Harima Heavy Industries Co., Ltd., Aioi. (Кове)

Ishikawajima-Harima Heavy Industries Co., Ltd., Nagoya Shipyard. (Kobe)

Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo. (Yorohama)

Kawasaki Heavy Industries, Ltd., Kawasaki. (Үоконама)

Kawasaki Heavy Industries, Ltd., Kobe. (Kobe) Kobe Steel, Ltd., Okubo Plant, Akashi City. (Kobe)

Mitsubishi Heavy Industries Ltd., Kobe Shipyard & Engine Works, Kobe. (Кове)

Mitsubishi Heavy Industries Ltd., Hiroshima Shipyard & Engine Works, Hiroshima. (Нікозніма)

Mitsubishi Heavy Industries Ltd., Nagasaki Shipyard & Engine Works, Nagasaki. (Nagasaki)

Mitsubishi Heavy Industries Ltd., Yokohama Shipyard & Engine Works, Yokohama. (Yоконама)

Mitsui Shipbuilding & Engineering Co., Ltd., Fujinagata Works, Osaka. (Kobe)

Mitsui Shipbuilding & Engineering Co., Ltd., Tamano. (Kobe)

Nippon Kokan K.K., Tsurumi Shipyard. (Yоконама) Sasebo Heavy Industries, Co., Ltd., Sasebo. (Sasebo)

Sumitomo Shipbuilding & Machinery Co., Ltd., Kawawa Chemical Machinery Department, Yokosuka.

(Үоконама)

Norway

Elektrisk Sveisning A/S, Toyenbekken 34, Oslo. (Oslo) Fredriksstad Mek. Verksted, Fredrikstad. (Oslo) Kvaerner Brug A/S, Oslo. (Oslo)

Poland

Huta Ferrum, Katowice. (GDANSK)

Sosnowieckie Zaklady Budowy Kotlow, Sosnowiec.

(KATOWICE)

Stocznia Gdansk (Gdansk Shipbuilding, Marine Engineering & Boiler Works), Gdansk. (Gdansk)

South Africa

Barlows Heavy Engineering Ltd., Benoni, Transvaal. (Vereeniging)

Thompson, John, Africa (Pty.) Ltd., Bellville, Cape Province. (Cape Town)

Vecor Heavy Engineering Ltd., Duncanville Works, Houtkop Road, Duncanville. (Vereeniging)

Spain

Empresa Nacional Bazan, El Ferrol. (EL FERROL)

La Maquinista Terrestre y Maritima S.A., Barcelona.
(BARCELONA)

Mecanica de la Pena, Urduliz. (BILBAO)

S.E. de C. Babcock & Wilcox S.A., Galindo Works, Bilbao. (Bilbao)

Sweden

Aktiebolaget Gotaverken, Gothenburg. (GOTHENBURG)
Avesta Jernverks A/B, Avesta. (STOCKHOLM)
Eriksbergs Mek. Verkstads A/B, Gothenburg. (GOTHENBURG)
Karlstads Mek. Werkstad A/B, Karlstad. (GOTHENBURG)
Kockums Mek. Verkstads A/B., Malmo. (MALMO)
Motala Verkstad A/B, Motala. (GOTHENBURG)

LLOYD'S REGISTER OF SHIPPING

Switzerland

Brown, Boveri Ltd., Baden. (WINTERTHUR) Sulzer Brothers Ltd., Winterthur. (WINTERTHUR)

U.S.A.

Babcock & Wilcox Co., Barberton, Ohio. (CLEVELAND) Chicago Bridge & Iron Co., Birmingham, Alabama.

(MOBILE)

29th October, 1971

Combustion Engineering Co., Inc., Chattanooga, Tennessee.
(MOBILE)

Foster Wheeler Corporation, Mountaintop, Pa.

(PHILADELPHIA)

Yugoslavia

Djuro Djakovic, Slavonski Brod. (RIJEKA) Energoinvest T.A.T., Sarajevo. (RIJEKA) Tvornica Parnih Kotlova, Zagreb. (RIJEKA)

Chapter K

SPARE GEAR FOR STEAM AND OIL ENGINE MACHINERY INSTALLATIONS

Spare parts for the following items, so far as they are applicable, are to be carried. The spare parts are to be replaced or made good by the owners as opportunity occurs.

In the case of ships with multi-engine installations, the spare parts required need only be carried for one engine.

			SPARE P	ARTS REQUIRED TO BE CARRIED					
ITEM NO.	ITEM	NUMBER 1	REQUIRED						
		SHIPS FOR UNRESTRICTED SERVICE SERVICE		SPARE PARTS					
	MAIN F	ROPELLI	NG MAC	HINERY					
	STEAM RECIPROCATING EN	GINES (See a	lso item 25)						
		1	1	Bottom end bearing complete with liners, bold and nuts.					
1	Connecting Rod Bearings	1	1	Top end bearing complete with liners, bolts an nuts for one connecting rod.					
2	Piston Rings	1 set	1 set	Rings and springs for H.P. piston.					
3	Piston Valve Rings	1 set		Rings and springs, of each size fitted.					
4	Piston Rod Metallic Packing	1	-	Complete set of packing for H.P. piston rod an valve spindle.					
5	Poppet Valves	1		Valve complete with cage, spindle and bush, each size fitted, together with rollers and spring					
	STEAM TURBINES (See also ite	m 25)							
6	Bearing Bushes	1	-	Complete bearing bush, of each size and type fitted, for the rotor, pinion and gear wheel shaft for one engine.					
7	Turbine Thrust	1 set	1 set	Pads of each size for one face of Michell type thrust, or rings for turbine adjusting block, each size fitted for one engine. Assorted liners for 1 block where fitted.					
	OIL ENGINES (See also item 25)								
8	Main Bearings	1		Main bearings or shells for one bearing of eac size and type fitted, complete with shims, bol and nuts.					
9	Cylinder Liner	1	_	Cylinder liner, complete with joint rings are gaskets.					
10	Cylinder Cover	1	-	Cylinder cover, complete with valves, joint rin and gaskets. For engines without covers, the respective valves for one cylinder unit.					
		½ set		Cylinder cover bolts and nuts, for one cylinder.					

			SPARE I	*				
ITEM NO.	ITEM	NUMBER I	REQUIRED					
		SHIPS FOR UN- RESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	SPARE PARTS				
		2 sets	1 set	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder.				
11	Cylinder Valves	1 set	1 set	Air inlet valves, complete with casings, seats. springs and other fittings for one cylinder.				
**	Cymrat varvs	1	1	Starting air valve, complete with casing, seat, springs and other fittings.				
	you tel barries of this Jean Fellin	1	1	Relief valve, complete.				
	CONTROL OF STATES AND	1 set	i set	Fuel valves of each size and type fitted, complete with all fittings, for one engine.				
12	Connecting Rod Bearings	1 set		Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder.				
120	Pistons	1 set	-	Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder.				
10		1		Crosshead type: Piston of each type fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts.				
13	Piscons	1	1	Trunk piston type: Piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod.				
14	Piston Rings	1 set	-	Piston rings, for one cylinder.				
15	Piston Cooling	1 set		Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit.				
last last an	All of policy to public of	1 set	-	Gear wheel drive: Wheels for the camshaft drive of one engine.				
16	Gear and Chain for Camshaft Drives	6	-	Chain drive: Separate links with pins and rollers of each size and type fitted.				
		1 set	_	Bearing bushes of each type fitted.				
17	Cylinder Lubricators	1		Lubricator complete, of the largest size, with its chain drive or gear wheels.				
18	Fuel Injection Pumps	1	<u> </u>	Fuel pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.)				
19	Fuel Injection Piping	1	= 4	High pressure fuel pipe of each size and shape fitted, complete with couplings.				
20	Scavenge Blowers (including turbo-chargers)	1 set		Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if of other types. Note: Where an engine with one blower out of action can be manœuvred satisfactorily spare parts may be omitted.				
21	Scavenging System	1 set	-	Suction and delivery valves for one pump of each type fitted.				
22	Pedystion and/s Passes C	1 set	-	Complete bearing bush, of each size fitted in the gear case assembly.				
20	Reduction and/or Reverse Gear	1 set	_	Roller or ball race, of each size fitted in the gear case assembly.				

			SPARE PARTS REQUIRED TO BE CARRIED					
ITEM NO.	ITEM	NUMBER I	REQUIRED					
		SHIPS FOR UN- RESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	SPARE PARTS				
	Main Engine Drigen Air	1 set		Piston rings of each size fitted.				
23	Main Engine Driven Air Compressors	∦ set	_	Suction and delivery valves complete of e size fitted.				
24	Gaskets and Packings	-	1 set	Special gaskets and packings of each size an type fitted for cylinder covers and cylinder lines for one cylinder.				
	APPLICABLE TO ALL TYPE	S OF MAIN E	NGINES					
		1 set	1 set	Pads for one face of Michell type thrust bloc				
25	Main Thrust Blocks	1	1	Complete white metal thrust shoe of solid ring typ				
	25 Main Thrust Blocks		1	Inner and outer race with rollers where roller thrust bearings are fitted.				
	ELECTRIC PROPELLING MACHINERY	For items	of spare gear	to be carried, see M 21.				

AUXILIARY MACHINERY

Where additional units of adequate capacity are fitted no spare gear is required.

AUXILIARY OIL ENGINES For each type of engine required for essential services.

26	Main Bearings	1	_	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts.
		2 sets	-	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder.
		1 set	_	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder.
27	Cylinder Valves	1	_	Starting air valve, complete with casing, seat, springs and other fittings.
		1	THOU T	Relief valve, complete.
		½ set	_	Fuel valves of each size and type fitted, complete, with all fittings, for one engine.
	Connecting Rod Bearings	1 set		Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder.
28		1 set	_	Top end bearings or shells of each type fitted, complete with shims, bolts and nuts, for one cylinder.
		1 set	_	Trunk piston type: gudgeon pin with bush for one cylinder.
29	Piston Rings	1 set		Piston rings, for one cylinder.
30	Piston Cooling	1 set	_	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit.
31	Fuel Injection Pumps	1	-	Fuel pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valve springs, etc.)

			SPARE I	PARTS REQUIRED TO BE CARRIED				
ITEM NO.	ITEM	NUMBER	REQUIRED					
		SHIPS FOR UN- RESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	SPARE PARTS				
32	Fuel Injection Piping	1	iel	High pressure fuel pipe of each size and shape fitted, complete with couplings.				
33	Gaskets and Packings	1 set		Special gaskets and packings of each size and type fitted, for cylinder covers and cylinder liners for one cylinder.				
	AUXILIARY STEAM ENGINES	For each size	of engine re	quired for essential services				
34	Connecting Red Parallel	1	1	Bottom end bearing complete with liners, bolt and nuts.				
34	Connecting Rod Bearings	1	1	Top end bearing complete with liners, bolt and nuts.				
35	Piston Rings	1 set	1 set	Rings.				
	TURBINES DRIVING ESSENTIAL AUXILIARIES	Spare gear applicab	r to be the s	ame as for main steam turbines in so far as				
	AUXILIARY AIR COMPRESSOR							
36	Piston Rings	1 set	1 set	Rings, of each size fitted, for one piston.				
37	Valves	₫ set	1 set	Suction and delivery valves, complete, of each size fitted.				
	ELECTRICAL EQUIPMENT	For items	of spare gear t	o be carried, see M 21.				
	REFRIGERATING INSTALLATIONS IN SHIPS	For items	of spare gear t	o be carried, see N 6.				
	Trigota control give	BOII	LERS					
	MAIN AND							
	AUXILIARY BOILERS (See G 103)							
38	Tube Stoppers or Plugs	20	10	Tube stoppers or plugs, of each size used, for boiler, superheater and economizer tubes.				
39	Fire Bars	Fire Bars 1 set Oil Fuel Burners 1 set		Fire bars for one boiler, where coal fired.				
40	Oil Fuel Burners			Oil fuel burners complete, for one boiler.				
		2 sets per boiler	2 sets per boiler	Gauge glasses of round type.				
41 Gauge Glasses		1 set for every	1 set for every	Gauge glasses of flat type.				

Chapter L

CONTROL ENGINEERING EQUIPMENT

Section 1

GENERAL REQUIREMENTS

101 (a) This Chapter applies to both passenger ships and cargo ships, and is in addition to other relevant sections of the Rules.

(b) Whilst these requirements satisfy the regulations of the International Convention for the Safety of Life at Sea, 1960, attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

(c) This Chapter states requirements for systems of automatic or remote control which may be used for controlling the machinery contained in 102(b).

The design and installation of other control equipment is to be such that there is no risk of danger due to its failure.

(d) The details of control systems will vary with the type of machinery being controlled and special consideration will be given to each case.

Plans

102 (a) Where control systems are applied to essential machinery or equipment as listed in 102(b) plans are to be submitted in triplicate. They are to include or be accompanied by:—

Details of operating medium, i.e., pneumatic, hydraulic or electric, including standby sources of power.

Description and/or block diagram showing method of operation.

Line diagrams of control circuits whether open or closed loop.

List of points monitored.

List of alarm points.

List of control points.

Test facilities provided.

Test schedules.

Maintenance programmes, e.g., whether of modular construction so that repair by replacement is intended.

Spare gear, as recommended by the Manufacturer.

(b) Control Systems for which Plans are required:-

Ballast systems for dry cargo ships.

Bilge systems.

Cargo pumping systems for tankers.

Controllable pitch propellers.

Electric generating plant.

Evaporating and distilling systems for use with main steam machinery.

Fire detection systems.

Fire extinguishing systems.

Fuel oil transfer and storage systems.

Main propelling machinery including essential auxiliaries.

Steam raising plant.

Steel hatch covers.

Windlass.

(c) Alarm Systems

Details of the overall alarm system linking main control station, bridge area and accommodation are to be submitted.

(d) Control Stations

Details of control stations, including bridge control, are to be submitted.

(e) Standard Systems

Where it is intended to employ a system which has been previously approved it will be sufficient to refer to such previous approval. In such cases additional plans are not required.

Alarm and Control Equipment

103 Major units of equipment are to be surveyed at the manufacturer's works. Examples of such major units are:—

Bridge control consoles.

Boiler control consoles.

Display, alarm and data processing consoles.

The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended environment.

The Society will issue lists of approved components which have been successfully type tested for environment. A copy of the Society's Environmental Test Specification will be furnished on application.

Assessment of performance parameters, such as accuracy, rangeability and the like, are to be in accordance with an acceptable national or international standard.

Components used in control systems should, wherever practicable, be selected from the lists of approved equipment to be issued by the Society.

Alterations or Additions

104 When an alteration or addition to the approved system(s) is proposed plans are to be submitted for approval. The alterations or additions are to be carried out under the inspection and to the satisfaction of the Surveyors.

Section 2

UNATTENDED MACHINERY SPACES—"UMS" NOTATION (See B 301(c))

Essential Safety Features

201 Where it is proposed to operate the ship with unattended machinery spaces, no matter what period is envisaged, the safety features in 202 to 209 inclusive are to be installed.

Bridge Control

- 202 (a) Means are to be provided to ensure satisfactory control of propulsion from the bridge.
- (b) Instrumentation to indicate the following is to be fitted on the bridge:—
 - (i) Propeller speed,
 - (ii) Direction of rotation of propeller for a fixed pitch propeller or pitch position for a controllable pitch propeller,
 - (iii) Where a main propulsion engine is started from the bridge, indication that sufficient air pressure is available for manœuvring the engine.

Alarm System for Propulsion Machinery and Other Essential Machinery

- 203 An alarm system which will provide warning of faults in the essential machinery is to be installed. The system is to satisfy the following requirements:—
- (a) Machinery faults are to be indicated at the control station for machinery (see L 3).
- (b) Engineering personnel is/are made aware that a machinery fault has occurred.
- (c) If the bridge navigating officer of the watch is the sole watchkeeper, then in the event of a machinery fault being monitored at the control station for machinery (see 204), the alarm system is to be such that this watchkeeper is made aware when:—
 - (i) a machinery fault has occurred,
 - (ii) the machinery fault is being attended to,
 - (iii) the machinery fault has been rectified. Alternatively, the system of communication required by 204(b) may be used for this purpose.
- (d) The alarm system should, so far as practicable, be designed with self-monitoring properties.
- (e) Failure of power supply to the alarm system is to be indicated.
- (f) All alarms are to be both audible and visual. If arrangements are fitted to silence audible alarms they are not to extinguish visual alarms.
- (g) If the audible alarm has been silenced and a second fault occurs before the first can be rectified the audible alarm is again to operate.

Control Stations for Machinery

- 204 (a) A system of alarm displays is to be provided which readily ensures identification of faults in the machinery. For example, this may be provided by displays at a main control station or, alternatively, at subsidiary control stations. In the latter case, a master display is to be provided showing which of the subsidiary control stations is indicating a fault condition.
- (b) At the main control station (if provided) or close to the subsidiary stations (if fitted) there is to be provided means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery spaces.

The main control station and any other station from which the main propulsion machinery can be controlled are to be provided with means to indicate which station is in control.

Fire Detection Alarm System

- 205 (a) An automatic fire detection system is to be fitted in the machinery spaces together with an audible and visual alarm system.
- (b) A fire detector indicator panel is to be located in the navigating bridge area or in such a position that a fire in the machinery spaces will not render it inoperative. Where the machinery spaces are made up of separate compartments, e.g., generator rooms, purifier rooms, etc., the fire detector indicator panel should be sectionalised.
- (c) The audible fire alarm is to have a characteristic tone which distinguishes it from the alarm system required by 203. The audible fire alarm is to be audible on all parts of the navigating bridge and in accommodation areas.
- (d) The alarm system should, so far as practicable, be designed with self-monitoring properties.
- (e) Failure of power supply to the alarm system is to be indicated.
- (f) Detector heads of an approved type are to be located in the machinery spaces so that all potential fire outbreak points are guarded.
- (g) The fire detection system is to be capable of being tested.
- (h) It is to be demonstrated to the Surveyor's satisfaction that detector heads are located so that air currents will not render the system ineffective at sea and in port.
- (j) A drawing showing the location of the fire detector heads and the fire detector indicator panel is to be submitted.

Fire Prevention

- 206 (a) Means are to be provided to prevent leaks from high pressure oil fuel pipes dripping or spraying onto hot surfaces or, if applicable, into turbo-charger inlets. Such leakage preferably should be led to a collector tank fitted in a safe position with an alarm to indicate that leakage is taking place.
- (b) Means are to be provided to eliminate the possibility of overflow from daily service oil fuel tanks into the machinery spaces, and to safeguard against overflow of oil from the daily service oil fuel tanks through the air pipe. A suitable alarm may satisfy this latter requirement.

Bilge Level Alarm System

- 207 (a) An alarm system is to be provided to warn that liquid in the machinery space bilges has reached a pre-determined level and is to comply with 203. This level is to be sufficiently low to prevent liquid from overflowing from the bilges on to the tank top. In ships above 2000 gross tons at least two independent systems of level detection are to be provided.
- (b) Automatic starting of bilge pumps is not generally acceptable for the following reasons:—
 - (i) Leakage of liquid, either oil or water, into the bilges may be caused by a fault condition. If the bilge pump starts automatically, discovery of the fault condition may be delayed,
 - (ii) Considerations of sea pollution. Attention is drawn to the International Convention for the Prevention of Pollution of the Sea by Oil, 1954, and subsequent amendments.

However, arrangements with automatic starting may be considered, provided the Society is satisfied that the above requirements are met.

Supply of Electric Power

208 Arrangements are to be provided so that essential lighting in the machinery space is switched on automatically if the normal supply of electric power should fail.

Local Control of Essential Machinery

209 Arrangements are to be such that the essential machinery can be operated with the system of bridge control or any automatic controls out of action.

Section 3

ALARMS AND AUTOMATIC CONTROLS FOR PROPULSION AND OTHER ESSENTIAL MACHINERY—"UMS" NOTATION

General

301 Machinery for propulsion and other essential services is to be protected by the alarm system required by L 203, and machinery faults are to be identifiable at the main control station for machinery as required by L 204.

The minimum requirements for the alarm systems and automatic stop or shut down of different types of machinery installations are given in 302 to 305.

OIL ENGINES FOR PROPULSION PURPOSES

302 (a) The following systems are to be provided with alarms:—

System	Alarm
Lubricating oil for the	High temperature
engine including turbo	Loss of pressure
blower and gearing	
Cooling system(s)	High temperature
	Loss of pressure or loss of flow
Exhaust gas	High temperature
Starting air	Loss of pressure
Daily service fuel tanks	Low level
	High level—See L 206(b)
Sterntube bearing	Low level or high
lubricating oil system	temperature in bearing
Thrust bearing	High temperature

(b) Automatic Stop

In the case of the lubricating oil system, in addition to alarm indication as required by 302(a), the engine is to be stopped automatically for complete loss of lubricating oil. The circuit employed for this automatic stop is to be additional to the alarm circuit required by 302(a).

STEAM TURBINE MACHINERY FOR PROPULSION PURPOSES

303 (a) The following systems are to be provided with alarms:—

Alarm
Loss of pressure
High temperature
riigh temperature
Loss of vacuum
High temperature
High temperature
Loss of pressure
Low level or high
temperature in bearing
High temperature

(b) Automatic Stop

In the case of the lubricating oil system, in addition to alarm indication as required by 303(a), steam is to be shut off automatically from the turbine(s) for complete loss of lubricating oil. The circuit employed for this automatic shut off is to be additional to the alarm circuit required by 303(a).

(c) Lubricating Oil Supply

Where electric power is normally used to supply lubricating oil to the turbines and gearing, means are to be provided to safeguard the turbines from possible damage caused by rotation from propeller water torque if the normally connected supply of electric power should fail.

MAIN AND AUXILIARY BOILERS

Alarm and Fuel Shut-off Systems

- 304 (a) Two independent systems of water level detection are to be fitted which will operate alarms and shut off automatically the oil supply to the burners when the water level falls to a pre-determined low level. Both independent detectors are to be arranged to operate one actuator for fuel shut-off.
- (b) The oil fuel is to be shut off automatically from the burners, and alarms are to operate either on flame failure or failure of combustion air supply detected by either low pressure at fan outlet or stopping of fan motor.
- (c) Where the burner flame(s) is/are extinguished and re-ignited automatically in response to steam demand then after total flame failure re-ignition shall not take place until the furnace has been purged of explosive gases.
- (d) A low level alarm is to be fitted for the daily service oil fuel tanks. For high level of overflow alarm, see L 206(b).

Note. Only one independent system of water level detection, alarm and automatic oil supply shut-off, as described in 304(a), need be fitted in the case of small forced circulation or recirculation coiled water tube "package type" auxiliary boilers.

ELECTRIC GENERATING PLANT—"UMS" NOTATION

305 Alarms are to be provided to give warning of the following conditions:—

Operation of load shedding arrangements (see M 615).

Low voltage.

High voltage.

Low frequency.

Low lubricating oil pressure.

Low cooling water pressure or high cooling water temperature or loss of flow.

For parallel running a.c. generators, the alarms for low voltage, high voltage and low frequency may be satisfied by suitable system design.

Section 4

CONTROLLABLE PITCH PROPELLERS—"UMS" NOTATION

- 401 (a) A pitch indicator is to be fitted at each station from which it is possible to control the pitch of the propeller.
- (b) Means are to be provided to prevent the engine and shafting being subjected to excessive torque due to changes in propeller pitch; alternatively, an engine overload indicator may be fitted at each station from which it is possible to control the pitch of the propeller.
- (c) A stand-by or alternative power source of actuating medium for controlling the pitch of the propeller blades is to be fitted.

Section 5

CRITICAL SPEEDS-"UMS" NOTATION

501 Prolonged running in a restricted speed range is to be prevented automatically; alternatively, indication of restricted speed ranges is to be provided at each control station.

Section 6

REQUIREMENTS FOR UNATTENDED MACHINERY SPACES IN TUGS, COASTERS AND OTHER SMALL SHIPS HAVING PROPULSION MACHINERY OF LESS THAN 2000 SHP—"UMS" NOTATION

- 601 The requirements of L 2 are to be applied. In addition, the alarm system is to indicate the following:—
 - (a) Failure of control medium for bridge control system.
 - (b) Low lubricating oil pressure for main and auxiliary diesel engines.
 - (c) Low cooling water pressure or high cooling water temperature for main and auxiliary diesel engines.
 - (d) Boiler flame failure and low water level independently.

Section 7

ATTENDED MACHINERY SPACES

701 Where it is proposed to operate the ship with attended machinery spaces, and control equipment is fitted to the essential machinery, means are to be provided so that such machinery can be operated with any automatic control system(s) out of action.

Section 8

CARGO, BILGE AND BALLAST VALVES WITH REMOTE OR AUTOMATIC CONTROL

- 801 Where cargo or ballast valves are operated by remote or automatic control and bilge valves by remote control, the system of control should include the following safety features:—
 - (a) Failure of actuator power should not permit a valve to open inadvertently.
 - (b) Indication is to be provided at the remote control station for these services that the valve is open or closed.
 - (c) Equipment located in places which may be flooded should be capable of operating when submerged.
 - (d) A secondary means of operating the valves, which may be manual control, is to be provided. (See E 250.)

Section 9

TRIALS

901 Before a new installation, or any alteration or addition to an existing installation, is put into service trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the test schedules list called for in L 102.

It will be expected that most of these trials will be carried out before the sea trials of the ship.

15th January, 1970

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Chapter M

ELECTRICAL EQUIPMENT AND ELECTRIC PROPELLING MACHINERY

Section 1

GENERAL REQUIREMENTS

- 101 (a) The requirements of this Chapter apply to passenger ships and cargo ships except where otherwise stated. While these requirements are considered to meet those of the 1960 Safety of Life at Sea Convention, attention should be given to any relevant statutory regulations of the National Authority of the country in which the ship is to be registered.
- (b) In passenger ships services essential for safety are to be maintained under emergency conditions and the safety of ship and personnel from electrical hazards is to be assured.
- (c) This Chapter states requirements for those features of the electrical installation which are considered essential for the safety of the ship. The design and installation of other equipment is to be such that there is no risk of fire due to its failure. It must, as a minimum, comply with a national or international standard.
- (d) The Committee will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules. Consideration will also be given to the electrical arrangements of small ships and ships to be assigned class notations for restricted or special services.
- (e) Electrical installations for propulsion and auxiliary services are to be constructed and installed in accordance with the relevant sections of this Chapter and are to be inspected and tested by the Surveyors.

Plans

102 The following plans and particulars are to be submitted in triplicate, for consideration:—

PROPULSION EQUIPMENT

Plans of generators, motors and seatings together with diagrams of control gear, cables and circuits, and particulars of voltage, current, power and speed with a key diagram and explanation of the system in relation to the requirements of M 17.

ELECTRIC SLIP COUPLINGS

Plans showing the scantlings and construction of the couplings together with diagrams of electrical components, switchgear and control gear.

ELECTRICAL EQUIPMENT (other than propulsion equipment)

The arrangement plan and circuit diagram of the switchboard(s). Diagrams of the wiring system including cable sizes, type of insulation, normal working current in the circuits and the capacity, type and make of protective devices. Calculations of short-circuit currents at main busbars, sub-switchboard busbars and the secondary side of transformers are to be submitted. (See M 611.)

WELDING ON SHAFTS

Where welding is to be applied to shafts of machines for essential services for securing armature arms or spiders, plans showing the construction are to be submitted for consideration.

PRIME MOVERS

See G 104.

Tankers (compartments in between deck spaces) See M 1605.

CENTRALISED, BRIDGE OR AUTOMATIC CONTROLS See F 105 and Chapter L.

Additions or Alterations

103 An addition, temporary or permanent, is not to be made to the approved load of an existing installation until it has been ascertained that the current-carrying capacity and the condition of the existing accessories, conductors and switchgear are adequate for the increased load. (See C 108.)

Plans are to be submitted for approval and the alterations or additions are to be carried out under the inspection and to the satisfaction of the Surveyors.

Application

104 Except where a specific statement is made to the contrary all requirements of this Chapter are applicable to both alternating current and direct current installations.

105 D.C. equipment is to operate satisfactorily under voltage fluctuations of plus 6 per cent and minus 10 per cent.

A.C. equipment is to operate satisfactorily under voltage fluctuations of plus 6 per cent and minus 10 per cent at rated frequency and under frequency fluctuations of plus or minus 2,5 per cent at rated voltage.

Contactors and similar equipment are not to drop out at or above 85 per cent rated voltage.

Ambient Temperatures

106 The following cooling air and cooling water temperatures are applicable in ships classed for:—

(a) Unrestricted Service

(i) Primary cooling water supply

30°C (86°F)

(ii) Cooling air temperature

45°C (113°F)

(b) RESTRICTED SERVICE (See B 109 and B 110)

Vessels intended solely for use in northern or southern waters outside the tropical belt.

(i) Primary cooling water supply

25°C (77°F)

(ii) Cooling air temperature

40°C (104°F)

Location and Construction

107 Electrical equipment is to be accessibly placed clear of flammable material in well ventilated, adequately lighted spaces in which flammable gases cannot accumulate and where it is not exposed to risk of mechanical injury or damage from water, steam or oil. Where necessarily exposed to such risks the equipment is to be suitably constructed or enclosed. Live parts are to be guarded where necessary.

Insulating materials and insulated windings are to be resistant to tracking, moisture, sea air and oil vapour unless special precautions are taken to protect them.

Equipment is not to remain alive through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronizing switches and/or plugs.

The operation of all electrical equipment and the lubricating arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice, and with the ship inclined from the normal at any angle up to 15 degrees transversely, when pitching 10 degrees longitudinally and when rolling up to 22,5 degrees from the vertical.

All nuts and screws used in connection with currentcarrying parts and working parts are to be effectively locked.

Conductors and equipment are to be placed at such a distance from the magnetic compasses or are to be so disposed that the interfering magnetic field is negligible even when circuits are switched on and off.

Where electric power is used for propulsion, the equipment is to be arranged so that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to floor plate level. See E 223 and E 224.

Earthing

- 108 (a) Non-current-carrying metal parts of electrical equipment are to be effectively earthed. Where earthing connections are necessary they are to be of copper or other approved material and are to be protected against damage and, where necessary, electrolytic action. In general, they are to be equal to the cross section of the current-carrying conductor up to 16 mm² (0.0225 in²). Above this figure they are to be equal to at least half the cross section of the current-carrying conductor with a minimum of 16 mm² (0.0225 in²).
- (b) PORTABLE EQUIPMENT—Metal frames of all portable electric lamps, tools and similar apparatus supplied as ship's equipment and rated in excess of 55 V are to be earthed through a suitable conductor unless equivalent safety provisions are made such as by double insulation or by an isolating transformer.

Flameproof and Intrinsically Safe Equipment

109 Where risk of explosion might otherwise arise, equipment is to be of flameproof or intrinsically safe type.

Where equipment is required to be of flameproof or intrinsically safe type and equipment of suitable type is obtainable which has been type tested and approved by a competent independent Testing Authority, it will be sufficient to furnish a copy of the relevant certificate, provided that there is no departure from the design so tested and approved.

Note:-

(i) A flameproof enclosure is one which will withstand without injury any explosion of the prescribed flammable gas that may occur within it under practical conditions of operation, and will prevent the transmission of flame such as will ignite the flammable gas in the surrounding atmosphere. (ii) Intrinsically safe apparatus is to be so constructed that when installed and operated under the conditions specified by the Certifying Authority, any electrical sparking that may occur in normal working, either in the apparatus or in its associated circuit, is incapable of causing an ignition of the prescribed flammable gas or vapour.

Creepage and Clearance

110 The distances between live parts and between live parts and earthed metal whether across surfaces or in air shall be adequate for the working voltage having regard to the nature of the insulating material and the transient over-voltages developed by switch and fault conditions.

For bare busbars the following minimum clearance distances shall be observed:—

Voltage between	Minimum clearance to earth					Minimum clearance between phases or poles					
phases or poles	In air		In oil		In air		In oil				
	mm	in	mm	in	mm	in	mm	in			
660 or less	16	0.625	_	_	19	0.75	-	-			
2200	38	1.5	-	-	38	1.5	-	-			
3300	51	2	13	0.5	51	2	19	0.78			
6600	63	2.5	19	0.75	89	3.5	25	1.0			

Where necessary these figures are to be increased to allow for the electro-magnetic forces involved.

Emergency Source of Power

111 An emergency source of power, capable of functioning when the ship is inclined 22,5 degrees and/or when the trim of the ship is 10 degrees, is to be installed in accordance with the following:—

Where emergency generating sets are fitted they are to be capable of being started readily when cold.

If hand starting is demonstrated to be practicable, alternative means of starting are not required. Where hand starting is not practicable other means are to be provided and, in general, should provide for not less than 12 starts in a period of 30 minutes without recourse to sources of power within the machinery space.

I PASSENGER SHIPS

(a) A self-contained emergency source of electric power is to be installed above the bulkhead deck and outside the machinery casings. Its location in relation to the main source or sources of electric power is to be such as to ensure that a fire or other casualty to the machinery spaces (i.e.,

spaces containing the main and auxiliary propelling machinery, boilers serving the needs of propulsion and all permanent coal bunkers) will not interfere with the supply or distribution of emergency power. It is not to be forward of the collision bulkhead.

- (b) The power available is to be sufficient to supply all services necessary for the safety of passengers and crew in an emergency, due regard being paid to such services as may have to be operated simultaneously. Special consideration is to be given to emergency lighting at every boat station on deck and oversides, in all alleyways, stairways and exits, in the machinery spaces and in the control stations (i.e. spaces in which radio, main navigating or central fire recording equipment or the emergency generator is located), to fire detection and alarm systems, to the sprinkler pumps, to navigation lights and to the daylight signalling lamp, if operated from the main source of power. The power is to be adequate for a period of 36 hours, except that, in ships engaged regularly on voyages of short duration a lesser supply will be specially considered.
 - (c) The emergency source of power is to be either:—
- (i) A generator driven by a suitable prime mover with an independent fuel supply and with satisfactory starting arrangements; the fuel used is to have a flash point of not less than 43°C (110°F); or
- (ii) An accumulator (storage) battery capable of carrying the emergency load without recharging or excessive voltage drop.
- (d) (i) Where the emergency source of power is a generator a temporary source of emergency power is to be installed. This is to be an accumulator battery of sufficient capacity:—
 - (a) To supply emergency lighting continuously for 30 minutes;
 - (b) To close the watertight doors (if electrically operated) but not necessarily to close them simultaneously;
 - (c) To operate the indicators (if electrically operated) which show whether power operated watertight doors are open or closed; and
 - (d) To operate the sound signals (if electrically operated) which give warning that power operated watertight doors are about to close.
 - (e) To operate the fire detection and alarm systems.

Arrangements are to be such that the temporary source of emergency power will come into operation automatically in the event of failure of the main electrical supply.

- (ii) Where the emergency source of power is an accumulator battery arrangements are to be such that emergency lighting will automatically come into operation on failure of the main lighting supply.
- (e) An indicator is to be mounted in the machinery space, preferably on the main switchboard, to indicate when any accumulator battery fitted in accordance with this Rule is being discharged.
- (f) (i) The emergency switchboard is to be installed as near as is practicable to the emergency source of power.
- (ii) Where the emergency source of power is a generator, the emergency switchboard is to be located in the same space as the emergency source of power, unless the operation of the emergency switchboard would thereby be impaired.
- (iii) No accumulator battery fitted in accordance with this Rule is to be installed in the same space as the emergency switchboard.
- (iv) The emergency switchboard may be supplied from the main switchboard during normal operation.

II CARGO SHIPS

- (a) A self-contained emergency source of power is to be fitted. This may be either:—
- (i) An accumulator (storage) battery capable of carrying the emergency load without recharging or excessive voltage drop; or
- (ii) A generator driven by a suitable prime mover with an independent fuel supply and with satisfactory starting arrangements; the fuel is to have a flash point not less than 43°C (110°F).
 - (b) Cargo Ships of 5000T gross tonnage and above
- (i) The emergency source of power is to be located above the uppermost continuous deck and outside the machinery casings.
- (ii) The power available is to be sufficient to supply all services necessary for the safety of all on board in an emergency.

Special consideration is to be given to:-

- (a) Emergency lighting at every boat station on deck and oversides, in all alleyways, stairways and exits, in the main machinery space and the main generating set space, on the navigating bridge and in the chartroom.
 - (b) The general alarm.

- (c) Fire detection and alarm systems.
- (d) Navigation lights if solely electric and the daylight signalling lamp if operated by the main source of power.
- (iii) The power is to be adequate for at least six hours operation.
 - (c) CARGO SHIPS OF LESS THAN 5000T GROSS TONNAGE

The emergency source of power is to be capable of supplying the illumination at launching stations and stowage positions of survival craft in addition to the emergency lighting, together with the fire detection and alarm systems.

The power available is to be adequate for at least three hours operation.

Section 2

SYSTEMS OF SUPPLY

201 The following systems of distribution may be used:—

(a) Parallel systems with constant pressure

DIRECT CURRENT

Two wire

Three wire with mid-wire earthed.

ALTERNATING CURRENT

Single-phase-two wire

Three-phase-

Three wire

Four wire with neutral earthed but without hull return.

Systems employing single wire with hull return may be submitted for special consideration.

- (b) Series systems with constant current (direct current only).
- 202 For parallel systems with constant pressure, system voltages for both alternating current and direct current shall not exceed:—
 - 500 V for generation, power, cooking and heating equipment permanently connected to fixed wiring.
 - 250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above.

203 In very large alternating current installations generation and limited distribution at higher voltages (e.g., $3.3\,\mathrm{kV}$) may be submitted for special consideration. See M 18.

Section 3

DIVERSITY FACTOR

301 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

The diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear.

Winch Circuits

302 For winches the diversity factor is to be calculated and submitted.

Section 4

ROTATING MACHINERY

Governors

401 Where a turbine driven direct current generator is arranged to run in parallel with other generators, a switch is to be fitted to each turbine to open the generator circuit-breaker when the overspeed protective device functions. See H 828 and H 926.

402 The facilities for adjusting the governor of an alternating current generating set, at normal frequency, are to be sufficiently fine to permit an adjustment of load on the engine within 5 per cent of full load.

Number of Generators

403 The number and ratings of ships' service generating sets and converting sets are to be sufficient to ensure the operation of services essential for the propulsion and safety of the ship and preservation of the cargo even when one generating set or converting set is out of service.

Rating

404 Ships' service generators, including their exciters and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling

air or water temperature for an unlimited period, without the limits of temperature rise in 405 being exceeded. Other generators and motors are to be rated in accordance with the duty which they are to perform and when tested under rated load conditions the temperature rise is not to exceed the values in 405.

Temperature Rise

405 Ships for Unrestricted Service

Table M 4.1 gives the limits of temperature rise above the cooling air temperature for machines not fitted with water coolers and above the cooling water temperature for machines fitted with coolers, for machines intended to operate in ships classed for unrestricted service.

SHIPS FOR RESTRICTED SERVICE (See M 106)

For machines intended to operate in ships classed for restricted service as defined in M 106 the temperature rises given may be increased by 5 degC (9 degF) for all machines.

If it is known that the temperature of the cooling medium exceeds the values given in M 106 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

406 The limits of temperature rise of electric slip couplings are to be in accordance with Table M 4.1 except that when a squirrel cage element is used the temperature of this element is not to reach an injurious value. The temperature of the field windings is not to exceed these limits at all speeds of operation. Arrangements for reducing the excitation of self-ventilated couplings at low operational speeds are permissible.

407 Alternating current machines of 5000 h.p. or kVA output and above, and propulsion motors having a total axial core length of 1 m or more are to have at least three embedded temperature detectors. With multi-core machines the total length is to be taken as the sum of the individual core lengths.

Overloads

408 Machines are to withstand, on test, without injury, the following momentary overloads:—

Generators: An excess current of 50 per cent for 15 sec. after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The foregoing does not apply to the overload torque capacity of the prime mover.

TABLE M 4.1

TEMPERATURE RISE IN DEGREES CENTIGRADE

					Temp	erature	-rise °	C	
IT	ITEM PART OF MACHINES		Method of Measurement of Temperature	Air-cooled machines Class			Water-cooled machines Class		
				A	E	В	A	E	В
1.	(a) (b)	A.C. windings of turbine-type machines having output of 5000 kVA or more	ETD or R	50	60	70	70	80	90
2.	(a) (b)	A.C. windings of machines smaller than in Item 1 Field windings of a.c. and d.c. machines having d.c. excitation	R	50	65	70	70	85	90
	(c)	other than those in Items 3 and 4	T	40	55	60	60	75	80
3.		Field windings of turbine-type machines having d.c. excitation	R		-	80	_		100
4.	(a)	Low-resistance field windings of more than one layer, and compensating windings	T, R	50	65	70	70	85	90
y F	(b)	Single-layer windings with exposed bare surfaces	T, R	55	70	80	75	90	100
5.		Permanently short-circuited insulated windings	T	50	65	70	70	85	90
6.		Permanently short-circuited windings, uninsulated	T	shal	temper	case r	each s	uch a	value
7.		Iron core and other parts not in contact with windings		that there is a risk of injury to insulating or other materia adjacent parts					
8.		Iron core and other parts in contact with windings	T	50	65	70	70	85	90
9.		Commutators and slip-rings, open or enclosed	T	50	60	70	70	80	90

Note 1. T = Thermometer method

R = Resistance method

E.T.D. = Embedded temperature detector

- NOTE 2. When the commutators, sliprings or bearings of machines provided with water coolers are not in the enclosed air circuit cooled by the water cooler, but are cooled by the ambient cooling air, the permissible temperature-rise above the ambient cooling air should be the same as for ventilated machines.
- Note 3. When Class F or Class H insulation is employed the permitted temperature rises are respectively 20degC and 40degC higher than the values given for Class B insulation.
- Note 4. Classes of insulation are to be in accordance with IEC Publication No. 85 (1957)—Recommendations for the Classification of Material for the Insulation of Electrical Machinery and Apparatus in relation to their thermal stability in service.

Motors: At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load.

D.C. motors	***	***	1444		50% for 15 sec	
Polyphase A.C.	synchr	onous 1	notors		50% for 15 sec	
Polyphase A.C	. syncl	ronous	indu	etion		
motors	***	***	4.4.4		35% for 15 sec	
Polyphase A.C. induction motors					60% for 15 sec	

The overload tests for propulsion machines will be specially considered for each installation.

Short-Circuit

409 The stator and rotor windings of alternating current propulsion generators are to be capable of withstanding a momentary short-circuit at the terminals of the machine applied when generating full rated voltage. Ships' service generators are to be capable of withstanding the mechanical and thermal effects of fault current for the duration of any time delay which may be fitted in a tripping device for discrimination purposes.

Shaft Currents

410 Means are to be taken to prevent the ill effects of flow of currents circulating between the shaft and bearings.

Welding on Shafts

411 Where welding is applied to shafts of machines for securing armature arms or spiders, stress relieving is to be carried out after welding.

Brushgear

412 The final running position of brushgear is to be clearly and permanently marked.

Direct current motors and generators are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

Alternating current commutator motors are to work over the specified range of load and speed without injurious sparking.

Direct Current Service Generators

413 Automatic voltage regulators are to be provided for shunt wound d.c. generators.

- 414 Direct current generators used for charging batteries without series-regulating resistors are to be either
 - (i) shunt wound
- or (ii) compound wound with switches arranged so that the series winding can be switched out of service.
- 415 Means are to be provided at the switchboard to enable the voltage of each generator to be adjusted separately.

For each direct current generator, coupled to its prime mover, at any temperature within the working range the means provided is to be capable of adjusting the voltage at any load between no load and full load to within:—

- 0,5 per cent of rated voltage for generators of rating exceeding 100 kW.
- 1,0 per cent of rated voltage for generators of rating not exceeding 100 kW.
- 416 The inherent regulation of ships' service generators is to be such that the following conditions are satisfied:—

For shunt or stabilised shunt wound generators when the voltage has been set at full load, the steady voltage at no load shall not exceed 115 per cent of the full load value, and the voltage obtained at any intermediate value of load shall not exceed the no load value.

For compound wound generators with the generator at full load operating temperature and starting at 20 per cent load with voltage within 1 per cent of rated voltage, then at full load the voltage is to be within 2,5 per cent of rated voltage. The average of the ascending and descending load/voltage curves between 20 per cent load and full load is not to vary more than 4 per cent from rated voltage.

- 417 Generators are to be capable of delivering continuously the full load current and normal rated voltage at the terminals when running at full load engine speed at all ambient temperatures up to the specified maximum.
- 418 Generators required to run in parallel are to be stable from no load up to the total combined load of the group and load sharing is to be satisfactory.
- 419 The series winding of each two-wire generator is to be connected to the negative terminal.

420 Equaliser connections are to have a cross-sectional area appropriate to the system but in no case less than 50 per cent of that of the negative connection from the generator to the switchboard.

Alternating Current Service Generators

- 421 Each alternating current service generator, unless of the self-regulated type, is to be operated in conjunction with a separate automatic voltage regulator.
- 422 The voltage regulation of any alternating current generator with its AVR is to be such that at all loads from zero to full load the rated voltage at rated power factor is maintained under steady conditions within ± 2.5 per cent.
- 423 In alternating current systems with one generator set out of action, the remaining set(s) are to have sufficient reserve capacity to permit the starting of the largest motor in the ship without causing any motor to stall or any other device to fail due to excessive voltage drop on the system.
- 424 Alternating current generators required to run in parallel are to be stable from 20 per cent full load (kW) up to the total combined full load (kW) of the group and load sharing is to be satisfactory.
- 425 When generators are operated in parallel the kVA loads of the individual generating sets are not to differ from their proportionate share of the total kVA load by more than 5 per cent of the rated kVA output of the largest machine when operating at 0,8 power factor.

Inspection and Testing

426 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured shall be recorded. Shaft materials are to comply with Chapter Q.

Generators of 100 kW or over and motors of 100 h.p. and over intended for essential services are to be inspected by the Surveyors during manufacture and testing. (A list of essential services is given in M 2102). Shaft materials are to be tested in accordance with Q 6.

427 In the case of duplicate machines up to 50 kW, kVA or bhp per 1000 r.p.m. type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated

tests on each machine. This is not to apply to propulsion machines. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

High Voltage Test

428 A high voltage test of 1000 V plus 2 × rated voltage with a minimum of 2000 V is to be applied to new machines preferably at the conclusion of the temperature rise test. The test is to be applied between the windings and the frame with the core connected to the frame and to any windings (or sections of windings) not under test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately. The test is to be made with alternating voltage at any convenient frequency between 25 and 100 cycles per second of approximately sine wave form. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for one minute, and then reduced to one-third full value before switching off.

When it is desired to make additional high voltage tests on a machine which has already passed its tests the voltage of such additional tests is to be 75 per cent of the figure given above.

Motors for Refrigerated Cargo Services

429 Motors intended for coupling to fans for the circulation of air in refrigerated cargo spaces are to be inspected by the Surveyors during manufacture and testing.

Plans showing the construction of the motors are to be submitted for consideration.

Fan motors fitted in the air stream are to be totally enclosed or otherwise suitably enclosed to withstand the effects of excessive moisture where they are fitted between the two sections of a cooler or where the air from the cooler passes over the motor.

The Surveyors will witness a type test on the first motor of each size and type and works test certificates are to be supplied for the remainder. This type test may also be accepted for repeat orders of motors identical in all essential respects provided cross-references are given in the works test certificates. Type tests need not be carried out for motors of the same frame size as one previously tested for higher output.

Where motors are mounted in the air stream but are to be tested in still air conditions generally two conditions arise:—

- (i) The motor may be open at one end or both ends when tested but totally enclosed when mounted in the air stream. In such cases a type test should be carried out under working conditions, i.e., in the trunking with the fan and fairings in place, or alternatively, calculations furnished to show that the Rules for temperature rise are complied with.
- (ii) The motor may be totally enclosed but with streamlined fairings. These may be accepted if, when tested in still air, the temperature rises are within the requirements of the Rules for totally enclosed motors. If they are outside these requirements the procedure in (i) is to be followed.

Electric Slip Couplings

430 Slip couplings are to be inspected by the Surveyors during manufacture and testing. Unless otherwise approved, every coupling is to be tested at the makers' works, the tests to include:—

Temperature rise test.

High voltage test.

Insulation resistance is to be recorded, together with the temperature at which it was measured.

Section 5

DISTRIBUTION

Final Sub-Circuits

501 A final sub-circuit of rating exceeding 15A is not to supply more than one point. The number of lighting points supplied by a final sub-circuit of rating 15A or less is not to exceed:—

" 220—250 V " 18,

except that in final sub-circuits for cornice lighting, panel lighting and electric signs where lampholders are closely grouped the number of points supplied is unrestricted provided the maximum operating current in the sub-circuit does not exceed 10A.

502 A separate final sub-circuit is to be provided for every motor required for essential services.

- 503 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. (This does not apply to cabin fans and wardrobe heaters).
- 504 Lighting of cargo spaces and coal bunkers is to be controlled by multi-pole linked switches situated outside these spaces. Provision is to be made for the complete isolation of these circuits and locking in the off position of the means of control.

Navigation Lights

505 Navigation lights are to be connected separately to a distribution board reserved for this purpose only, and connected directly or through transformers to the main or emergency switchboard. The distribution board is to be accessible to the officer of the watch.

Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuitbreaker mounted on the distribution board.

Where the navigation panel is situated in the midships house, the midships sub-switchboard is regarded as an extension of the main switchboard providing it is supplied from the main switchboard by two cables each capable of carrying full load.

Each navigation light is to be provided with an automatic indicator giving aural and/or visual indication of failure of the light. If an aural device alone is fitted it is to be connected to a primary or secondary battery. If a visual signal is used connected in series with the navigation light means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to tugs, trawlers, fishing and similar small vessels.

Provision is to be made on the bridge for such navigation lights to be transferred to an alternative circuit.

Any statutory requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

Steering Gear

- 506 (a) Only short-circuit protection and overload alarm are to be provided in steering gear circuits.
- (b) Indicators for running indication of steering gear motors are to be installed.

The exact position of the rudder, if power operated, is to be indicated at the principal steering station. (c) In all passenger ships and in cargo ships of 5000T gross tonnage and upwards electric and electro-hydraulic steering gear is to be served by two circuits fed from the main switchboard. One of the circuits may pass through the emergency switchboard. Each circuit is to have adequate capacity for supplying all the motors which are normally connected to it and which operate simultaneously.

If transfer arrangements are fitted in the steering gear room to permit either circuit to supply any motor or combination of motors, the capacity of each circuit is to be adequate for the most severe load conditions.

The circuits are to be separated throughout their length as widely as is practicable.

(d) In cargo ships of less than 5000T gross tonnage where electric power is the sole source of power for both main and auxiliary steering gear the supply arrangements are to comply with (c) above.

If the auxiliary steering gear is powered by a motor primarily intended for other services alternative protective arrangements to that required by sub-para. (a) will be specially considered.

(e) Where electric control of the steering system is fitted an alternative control system is to be installed. This may be a duplicate electrical control system or control by other means.

Fire Detection, Alarm and Extinguishing Systems

- 507 (a) Where electrically driven emergency fire pumps are installed in accordance with F 403 and F 505, the supply to such pumps is not to pass through the main machinery spaces.
- (b) Any fire alarm system is to operate both audible and visual signals at the fire detection control station(s). Detection systems for cargo spaces need not have audible alarms.
- (c) Electrical equipment used in operating fire detecting equipment is to have two sources of electrical power, one of which is to be the emergency source. (See M 111 and F 105 with Footnote.)

In addition, the following apply to passenger ships:-

(d) Where automatic sprinkler systems are fitted and electrical power is used for the operation of sea water pumps, air compressors and alarms fitted in conjunction with such systems at least two sources of power are to be arranged. The sources of power are to be a main generator and the emergency source of power. (See M 111.) One supply is to be taken from the main switchboard by separate feeders reserved solely for this purpose. Such feeders are to be run

to a change-over switch situated near the sprinkler unit and the switch is to be normally closed to the feeder from the emergency switchboard. The change-over switch is to be clearly labelled and no other switch other than those at the switchboard(s) is permitted in these feeders.

In passenger ships with aluminium superstructures where feeders from the emergency generator to the sprinkler unit pass through any space constituting a fire risk the cables are to be of fireproof type.

Heating and Cooking

508 Each item of heating or cooking equipment is to be controlled as a complete unit by a multi-pole linked switch mounted in the vicinity of the equipment. In the case of cabin heaters a single pole switch will be acceptable.

Shore Supply

- 509 (a) Where arrangements are made for the supply of electricity from a source on shore or elsewhere a suitable connection box is to be installed in a position in the ship suitable for the convenient reception of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals of ample size and suitable shape to facilitate a satisfactory connection. Suitable cables, permanently fixed, are to be provided, connecting the terminals to a linked switch and/or a circuit-breaker at the main switchboard.
- (b) For three-phase shore supplies with earthed neutral an earth terminal is to be provided for connecting the hull to the shore earth.
- (c) The shore connection is to be provided with an indicator at the main switchboard in order to show when the cable is energised.
- (d) Means are to be provided for checking the polarity (for direct current) or the phase sequence (for three-phase alternating current) of the incoming supply in relation to the ship's system.
- (e) At the connection box a notice is to be provided giving full information on the system of supply and the normal voltage (and frequency if alternating current) of the ship's system and the procedure for carrying out the connection.
- (f) Alternative arrangements may be submitted for consideration.

Submersible Bilge Pumps

510 Motors of permanently installed submersible bilge pumps are to be connected to the emergency switchboard (if fitted).

Cables and their connections to such pumps are to be capable of operating under a head of water equal to their distance below the bulkhead deck. The cables are to be suitable for operation in permanently wet situations, and installed in continuous lengths from above the bulkhead deck to the motor terminals.

Under all circumstances it is to be possible to start the motor of a permanently installed submersible bilge pump from a position above the bulkhead deck.

Section 6

SWITCHBOARDS, SWITCHGEAR AND PROTECTIVE EQUIPMENT

Switchboards

- 601 (a) An unobstructed space is to be left in front of switchboards. Pipes should, so far as possible, not be installed directly above or in front of or behind switchboards. If such placing is unavoidable suitable protection is to be provided in these positions. See E 275.
- (b) Where necessary the space at the rear of switchboards is to be ample to permit maintenance and in general not less than 0,6 m (24 in) except that this may be reduced to 0,5 m (18 in) in way of stiffeners or frames.
- (c) For voltages between poles or to earth above 55 V a.c. or 250 V d.c. dead-front switchboards are to be used. Where live parts on a switchboard are adjacent to a gangway an insulated handrail is to be provided and non-conducting mats or gratings are to be fitted at front and rear of the switchboard as necessary.
- (d) Section and distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorised persons have access, in which case the cupboard may serve as an enclosure.

All enclosures are to be constructed of, or lined with, non-flammable and non-hygroscopic material and are to be of robust construction.

(e) All measuring instruments and all apparatus controlling circuits are to be clearly and indelibly labelled for identification purposes. An indelible label is to be permanently secured to, or adjacent to, every fuse and every circuit-breaker and marked with particulars of the full load current of the generator or cable which the fuse or circuit-breaker protects. The labels for rewirable fuses are also to be marked with the appropriate size of fuse element. Where inverse time limit and/or reverse current devices are provided in connection with a circuit-breaker, the appropriate

settings of these devices are to be stated on the label. Nameplates are to be of flame-retardant material.

(f) In a passenger ship where there is only one main generating station the main switchboard is to be located in the same fire zone. Where there is more than one main generating station it is permissible to have only one main switchboard.

Busbars

602 Busbars and their connections are to be of copper, all connections being made so as to inhibit corrosion. Busbars and their supports are to be so designed as to withstand the mechanical stresses which will arise during short circuits. The maximum permissible temperature rise for bare conductors is 45 degC (81 degF).

Equaliser Connections

603 The current rating of equaliser connections and equaliser switches is to be not less than half the rated full load current of the generator. The current rating of equaliser bushars is to be not less than half the rated full load current of the largest generator in the group.

Instruments for Direct Current Generators

- 604 (a) For generators not operated in parallel at least one voltmeter and one ammeter are to be provided for each generator.
- (b) For parallel operation one ammeter is to be provided for each generator, and two voltmeters. One voltmeter is to be connected to the busbars and the other is to be capable of measuring the voltage of any generator.
- (c) For compound wound generators fitted with equaliser connections the ammeter is to be connected to the pole opposite to that connected to the series winding of the generator.
- (d) For three-wire generators the ammeter is to be located between the equaliser connection and the generator.
- (e) For three-wire systems supplied by a three-wire generator or by a balancing booster an ammeter is to be connected to each outer pole of each balancing generator and a voltmeter between each pole of the busbars and the middle wire.

Instruments for Alternating Current Generators

605 (a) For alternating current generators not operated in parallel each generator is to be provided with at least one voltmeter, one frequency meter and one ammeter with an ammeter switch to enable the current in each phase to be read or an ammeter in each phase and for generators above 50 kVA a wattmeter.

(b) For alternating current generators operated in parallel each generator is to be provided with a wattmeter, and an ammeter in each phase conductor or an ammeter with a selector switch to permit the measuring of current in each phase.

For paralleling purposes two voltmeters, two frequency meters and a synchronising device comprising either a synchroscope and lamps, or an equivalent arrangement, are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured.

Instrument Scales

- 606 (a) The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the normal voltage of the circuit and the normal voltage is to be clearly indicated.
- (b) The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.
- (c) Ammeters for use with direct current generators and kW meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse current or power respectively.

Instrument Transformers

607 The secondary windings of instrument transformers are to be earthed.

Earth Indication

608 Every insulated distribution system is to be provided with lamps or other means to indicate the state of insulation from earth.

Protection

- 609 Installations are to be protected against accidental overcurrents including short-circuit. The protective devices are to provide complete and co-ordinated protection to ensure:—
 - (i) Continuity of service under fault conditions through discriminative action of the protective devices.
 - (ii) Elimination of the fault so as to reduce damage to the system and hazard of fire.

Protection against Overload

610 Circuit-breakers and automatic switches provided for overload protection are to have tripping characteristics

appropriate to the system. Fuses above 320A are not to be used for overload protection, but may be used for short-circuit protection.

Over-current releases of circuit-breakers for generators and for circuits with preference tripping are to be adjustable.

Note.—Overload is considered to be an over-current in a circuit in which the insulation is still effective. Short-circuit is considered to be an over-current in a circuit in which the insulation is defective.

Protection against Short-Circuit

611 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

The breaking capacity of every protective device is to be not less than the maximum value of the short-circuit current which can flow at the point of installation at the instant of contact separation.

The making capacity of every circuit-breaker or switch intended to be capable of being closed, if necessary, on short circuit, is to be not less than the maximum value of the short-circuit current at the point of installation. On alternating current this maximum value corresponds to the peak value allowing for maximum asymmetry.

Every protective device or contactor not intended for short-circuit interruption is to be adequate for the maximum short-circuit current which can occur at the point of installation having regard to the time required for the short-circuit to be removed.

In the absence of precise data the following short-circuit currents at the machine terminals are to be assumed:—

D.C. Systems

Ten times full load current for generators normally connected (including spare).

Six times full load current for motors simultaneously in service.

A.C. SYSTEMS

Ten times full load current for generators normally connected (including spare)—symmetrical RMS.

Three times full load current for motors simultaneously in service.

Combined Circuit-breakers and Fuses

612 The use of a circuit-breaker of breaking capacity less than the prospective short-circuit current at the point of installation is permitted provided that it is preceded on the generator side by fuses, or by a circuit-breaker having at least the necessary breaking capacity. The generator breakers are not to be used for this purpose.

Fused circuit-breakers with fuses connected to the load side may be used where operation of the circuit-breaker and fuses is co-ordinated.

The characteristics of the arrangement shall be such that:—

- (i) When the short-circuit current is broken the circuit-breaker on the load side shall not be damaged and is to be capable of further service.
- (ii) When the circuit-breaker is closed on the shortcircuit current the remainder of the installation shall not be damaged. It is, however, admissible that the circuit-breaker on the load side may require servicing after the fault has been cleared.

Protection of Circuits

613 Short-circuit protection is to be provided in each live pole of a direct-current system and in each phase of an alternating-current system.

Overload protection is to be provided in:-

Two-wire d.c. or single-phase a.c. system—at least one line or phase.

Three-wire d.c. system—both outer lines.

Insulated three-phase a.c. system—at least two phases.

Earthed three-phase a.c. system—all three phases.

No fuse, non-linked switch or non-linked circuitbreaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors.

These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

Protection of Generators

- 614 In addition to over-current protection the following protective gear is to be provided as a minimum:—
- (a) For generators not arranged to run in parallel: A circuit-breaker arranged to open simultaneously all insulated poles or in the case of generators rated at less than 50 kW a multi-pole-linked switch with a fuse in each insulated pole.
- (b) For generators arranged to operate in parallel: A circuit-breaker arranged to open simultaneously all insulated poles. This circuit-breaker is to be provided with:—
 - (i) For direct-current generators, instantaneous reverse-current protection operating at not more than 15 per cent rated current,

(ii) For alternating-current generators a reversepower protection, with time delay, selected and set within the limits of 2 per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover.

The reverse-current protection is to be adequate to deal with the reverse-current conditions emanating from the ship's network, e.g., cargo winches. The reverse-power protection specified for alternating current generators may be replaced by other devices ensuring adequate protection of the prime movers.

- (c) In addition, the following is to be provided for direct-current generators arranged to operate in parallel.
 - (i) Where an equaliser connection is in use the reverse-current protection is to be provided in the pole opposite to that in which the series winding is connected.
 - (ii) For compound generators an equaliser switch for each generator so interlocked that it closes before and opens after the main contacts of the circuitbreaker with which it is associated, or a three-pole circuit-breaker with all poles operating simultaneously.
 - (iii) In three-wire systems a switch in the connection to the middle wire so interlocked with the generator switch or circuit-breaker connected to the outers as to operate simultaneously with them.

Essential Services

615 Where generators are operated in parallel and essential machinery is electrically driven arrangements are to be made to disconnect automatically the excess non-essential load when the generators are overloaded.

If required this load shedding may be carried out in one or more stages.

Circuits for cargo refrigeration machinery are to be included in the last group to be disconnected.

Power Transformers

616 The primary circuits of power transformers are to be protected against short-circuit by circuit-breakers or fuses.

When transformers are arranged to operate in parallel, means of isolation are to be provided on the secondary windings. Switches and circuit-breakers are to be capable of withstanding surge currents,

Feeder Circuits

617 Isolation and protection of each main distribution circuit is to be ensured by a multi-pole circuit breaker or switch and fuses. Protection is to be in accordance with 610, 611 and 613 except that steering gear circuits are to have short-circuit protection only and overload alarm. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

Circuits which supply motors fitted with overload protection may be provided with short-circuit protection only.

Motors of rating exceeding 0,5 kW/h.p. and all motors for essential services are to be protected individually against overload and short-circuit. The short-circuit protection can be provided by the same protective device for the motor and its supply cable. For essential motors which are duplicated the overload protection may be replaced by an overload alarm if desired by the owner.

For motors intended to provide uninterrupted service the protective gear is to have a delay characteristic to enable the motor to start, yet which will operate on overload before the windings reach an unacceptably high temperature. The current which the protective device will allow to pass indefinitely is not to exceed 125 per cent of the rated current.

For motors for intermittent service the current setting and the delay are to be chosen in relation to the load factor of the motor.

Lighting circuits are to be provided with overload and short-circuit protection.

Meters, Pilot Lamps, Capacitors

618 Protection is to be provided for voltmeters, voltage coils of measuring instruments, earth indicating devices and pilot lamps together with their connecting leads.

A pilot lamp installed as an integral part of another item of equipment need not be individually protected, provided it is fitted in the same enclosure. Where a fault in a pilot lamp would jeopardise the supply to essential equipment such lamps are to be individually protected.

Where capacitors for suppression of radio interference are fitted to busbars, generators, or steering-gear, fuses of appropriate size are to be connected in the capacitor circuit.

Switchgear

619 (a) Circuit-breakers and switches are to be of the air break type.

(b) The limits of temperature rise are to be based on the cooling air temperatures given in M 1, and when measured by thermometer or thermocouple are not to exceed:—

Contacts:

Solid copper		***	40	degC	(72	degF)
Silver or similar	112	1.00	65	degC	(117	degF)
Bare conductors						
and connectio	ns	VAC:	45	degC	(81	degF)

Coils

0118:					
Class A insulation	***	 50	degC	(90	degF)
Class E insulation	***	 65	degC	(117	degF)
Class B insulation		 80	degC	(144	degF)

- (c) Reports of tests to establish the capacity of circuitbreakers are to be submitted for consideration when required.
- (d) Each circuit opening device is to be so arranged that when placed in the OFF position it cannot accidentally move so as to close the circuit.
 - (e) Circuit-breakers are to be of the trip-free type.
- (f) The over-current releases of circuit-breakers for generators and the setting of preference tripping relays are to be adjustable, or if of the non-adjustable type are to be readily replaceable by others of different values.
- (g) Where reverse-power or reverse-current protection is provided it is to be appropriate to the circumstances of reverse-power between the limits of 2 per cent and 15 per cent of full load that may be expected. See 614(b).
- (h) A fall of 50 per cent in the applied voltage shall not render the reverse-current mechanism inoperative although it may alter the amount of reverse-current required to open the breaker.
- (i) Over-current releases are to be calibrated in amperes, and the settings marked on the circuit-breaker.
- (j) Handles and operating mechanisms are to be so arranged that the hand of the operator cannot accidentally touch live metal or be injured through an arc arising from the switch or circuit-breaker, or the rupturing of a fuse. If switches are enclosed their handles are not to operate through unprotected slots.

Testing

620 Before installation, switchboards complete or in sections with all components are to pass the following tests at the manufacturers' works and a certificate furnished. A high voltage test is to be carried out on all switching and control apparatus for systems greater than 60 V with a test voltage of 1000 V plus twice the rated voltage (minimum

2000 V) at any frequency between 25 c/s and 100 c/s for one minute applied between (i) all current-carrying parts connected together and earth and (ii) between current-carrying parts of opposite polarity or phase.

For systems of 60 V or less the test shall be at 500 V for one minute.

Immediately after the high voltage test the insulation resistance between (i) all current-carrying parts connected together and earth and (ii) between current-carrying parts of opposite polarity or phase, shall be not less than 1 megohm when tested with a d.c. voltage of at least 500 V.

Instruments and ancillary apparatus may be disconnected during the high voltage test.

Fuses

621 Fuses are to comply with an approved national standard or with the recommendations of the International Electrotechnical Commission and with the following clauses.

The breaking capacity of the fuse is to be not less than the prospective short-circuit current at the point of installation.

Fuses are to be suitable for operating in the ambient temperatures given in M 106 and the temperature rise at the terminals is to be such that the maximum permissible temperature(s) of the connected cable(s) is not exceeded.

- 622 Fuse-links and fuse-bases are to be marked with particulars of rated current and rated voltage. Each fuse position is to be permanently and indelibly labelled with the current-carrying capacity of the circuit protected by it and with the appropriate approved size of fuse or replaceable element.
- 623 A list of approved fuses will be issued. To secure approval a report, preferably by an independent authority, is to be submitted giving details of test performance, fusing characteristics, temperature and insulation tests and details of the specification to which the fuse had been tested. Outline drawings are to be included but samples should not be submitted unless requested.

Section 7

CONTROL GEAR

701 The limits of temperature rise for control gear are to be based on the cooling air temperatures given in M 106.

The temperature rise, at full rated load, measured by thermometer or thermocouple is not to exceed:—

Contacts:

Solid copper	6.6.6	100	60	degC	(108)	degF)
Silver or similar			75	degC	(135	degF)
Bare conductors						

and connections ... 45 degC (81 degF)

Coils:

Class A insulation	66	200	60	degC	(108	degF)
Class E insulation			75	degC	(135	degF)
Class B insulation	777	***	90	degC	(162	degF)

Resistors—maximum operating temperatures shall not exceed 410°C (770°F).

Other parts whether insulated or not are not to reach a temperature which might harm the parts themselves or materials with which they are in contact.

- 702 Control gear, including isolating and reversing switches is to be so arranged that shunt field circuits are not disconnected without an adequate discharge path being provided.
- 703 Every electric motor is to be provided with efficient means of starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW/h.p. is to be provided with the following control apparatus:
- (a) Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts. This does not apply to motors, the continuous availability of which is essential to the safety of the ship.
- (b) Efficient means of isolation are to be provided so that all voltage may be cut off from the motor and any associated apparatus including any automatic circuitbreaker.

Where the primary means of isolation (that provided at the switchboard, section board or distribution fuse board) is remote from a motor, one of the following is to be provided:—

- (i) An additional means of isolation fitted adjacent to the motor.
- or (ii) Provision made for locking the primary means of isolation in the OFF position.
- or (iii) Provision made so that the fuses in each line can be readily removed and retained by authorised personnel.

- (c) Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor (this does not apply to steering motors). See also M 617.
- (d) Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor against unacceptable overload in the case of single phasing.
- 704 When selecting motor control gear the maximum current of a motor is to be taken as the full load rated current of the motor.
- 705 Where a single master-starter system (e.g., a starter used for controlling a number of motors successively) is used the apparatus is to provide under-voltage and over-current protection and means of isolation for each motor not less effective than that required for systems using a separate starter for each motor. Where the starter is of the automatic type, suitable alternative means are to be provided for manual operation. Where the starter is used for motors for essential services the starting portion shall be duplicated and means are to be provided for the transfer of the starting duties in the event of failure of one of the starters.
- 706 Means are to be provided for stopping ventilating fans serving machinery and cargo spaces. These means are to be capable of being operated from outside such spaces in case of fire.

Machinery driving forced and induced draught fans, independently driven pumps delivering oil to main propulsion machinery for bearing lubrication and piston cooling, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps are to be fitted with remote controls situated outside the space concerned so that they may be stopped in the event of fire arising in the space in which they are located.

In passenger ships carrying more than 36 passengers all power ventilation systems, except cargo and machinery space ventilation, which is to be in accordance with the first sub-paragraph, are to be fitted with master controls so that all fans may be stopped from either of two separate positions which are to be situated as far apart as practicable.

707 Control gear and resistors are to be tested by the makers with a high voltage applied between the earthed frame and all live parts. The test voltage is to be 1000 V plus twice the rated voltage with a minimum of 2000 V. The voltage is to be alternating at any frequency between 25 and 100 c/s and is to be maintained for one minute without failure.

Immediately after the high voltage test the insulation resistance between (i) all current-carrying parts connected together and earth and (ii) between current-carrying parts of opposite polarity or phase, shall be not less than 1 megohm when tested with a direct current voltage of at least 500 V. Instruments and auxiliary apparatus may be disconnected during the high voltage test.

Section 8

CABLES

Conductors

801 High conductivity annealed copper only is to be used. For rubber-insulated cables the copper wire is to be tinned or alloy coated and the surface is to be bright.

Conductor composition and stranding is to be selected so that adequate flexibility of the finished cable is assured. Conductors of nominal cross-section 2,5 mm² (0.003 in²) and less need not be stranded. This requirement does not apply to mineral-insulated cables which have solid conductors. Cores of multi-core cables are to be readily identifiable.

Insulating Materials

802 The following insulating materials are permitted:—

TABLE M 8.1

Insulating Material	Maximum rated conductor Temp. °C	Maximum Ambient Temp. °C
Natural or synthetic rubber (general purpose)	60	50
Polyvinyl chloride compound (general purpose)	60	50
Natural or synthetic rubber (heat resisting)	75	65
Varnished cambric, Butyl	80	70
Asbestos-varnished cambric	85	75
Silicone rubber	95	-
Mineral	95	

NOTE. Silicone rubber and mineral insulation may be used for higher temperatures when installed where they are not liable to be touched by ship's personnel viz., silicone rubber 150°C mineral unlimited. Proposals to employ these higher temperatures will be specially considered.

Where a rubber or rubber-like material with maximum conductor temperature greater than 60°C is used it is to be readily identifiable.

Other insulating materials will be considered.

Insulation

803 (a) Rubber—The use of a single layer is permitted only when applied by the extrusion process. With other processes the insulation is to consist of at least two layers of rubber compound equal or different in quality (including polychloroprene compound but not pure rubber). The layers are to be bonded together.

The insulating wall is to be close fitting, but not adherent to the conductor.

- (b) POLYVINYLCHLORIDE—Polyvinylchloride insulation is to be applied by extrusion in one or more layers, is to be close fitting but not adherent to the conductor.
- (c) Varnished Cambric—Varnished cambric is to consist of a closely woven cloth tape uniformly coated on both sides with an insulating varnish. The average thickness of the finished cloth is to be not less than 0,13 mm (5 mils) nor more than 0,33 mm (13 mils).

The insulating wall is to consist of several layers of varnished-cambric tape, applied helically and smoothly, with or without overlapping, each tape covering the gap, if any of the underlying tape.

An insulating and lubricating compound is to be applied between the layers of varnished cloth so as to exclude air and moisture.

If a binder or identification tape is used and is made of insulating material it may be considered as part of the insulating wall.

- (d) ASBESTOS-VARNISHED CAMBRIC—The insulation of each conductor is to consist of a layer of felted asbestos, impregnated with heat and moisture resisting compound, plus layers of varnished cambric tape plus a layer of impregnated-felted asbestos. In place of felted asbestos, asbestos roving, glass roving, asbestos tape or glass tape may be used.
- (e) MINERAL INSULATION—Mineral insulation is to consist of a powdered mineral material, e.g., magnesium oxide, highly compressed between conductors and copper sheath. It is to be temperature-stable and non-corrosive to copper.

Construction

804 Whatever the insulating material used both the belted and non-belted construction may be used for two, three and more conductor cables.

Non-belted Cables

805 For non-belted cables the spaces among the cores are to be filled with fibrous or rubber-like fillers and the

cylindrical assembly is to be sheathed with the appropriate protective covering. Fillers may be omitted in multi-core cables having conductor sections 4,5 mm² (0.007 in²) or less.

Belted Cables

806 Belted cables are to be constructed as non-belted cables except that an insulating wall is to be applied to the cabled cores before applying the protective covering. For rubber or PVC-insulated cables the common belt is to be rubber or PVC respectively which may or may not form one body with the fillers.

Fillers

807 When fibrous fillers are used they are to consist of jute or similar rovings (including asbestos, glass, etc.), and are to be resistant to moisture.

When rubber-like fillers are used they are to consist of rubber (including regenerated and/or unvulcanized rubber) compounds or plastic compounds.

Sheaths and Protective Coverings

808 Cables are to be protected by one or more of the following and the sheath or protective covering is to be compatible with the insulation:—

Sheath Lead-alloy sheath

Copper sheath Non-metallic sheath

PROTECTIVE COVERING Steel-wire armour

Steel-wire armour Steel-tape armour Metal-braid armour (basket weave) Fibrous braid.

Unsheathed cables, e.g., rubber-insulated taped and braided or equivalent may be used only if installed in conduit.

- (a) Lead-Alloy Sheath—This is to be one of the recommended lead alloys given in I.E.C. Publication 92.
- (b) Copper—Copper sheath is permitted only for mineral-insulated cables.
- (c) METAL-BRAID ARMOUR (Basket weave)—This is to be formed of galvanized steel, copper or copper alloy or aluminium alloy wires. Aluminium alloy is to be corrosion-resistant. The coverage density of the braid is to be such that the weight of the braid is at least 90 per cent of the weight of a tube of the same metal having an internal diameter equal to the internal diameter of the braid and a thickness equal to the diameter of one of the wires forming the braid.

- (d) STEEL-WIRE ARMOUR—This is to consist of galvanized-annealed-steel wires having an elongation at break of at least 12 per cent. The wires are to be applied over the bedding so as to form a uniformly cylindrical layer and so as to ensure adequate flexibility of the cable.
- (e) Steel-Tape Armour.—This is to consist of annealedsteel tape. In general, the armour is to be formed of two tapes wound over the bedding in the same direction so that the gap in the first layer is not more than half the tape width and the second layer covers this gap with an overlap.

Note. Armour is to be protected against corrosion where necessary. A protective bedding is to be inserted beneath armour (of any type). This may be textile tape or braid, PCP tape or other suitable material. Textile materials are to be treated against moisture.

- (f) Non-Metallic Sheath—Polychloroprene compound and polyvinylchloride compound may be used for impervious sheaths. For asbestos varnished-cambric cables, asbestos sheath is permissible.
- (g) Fibrous Braid—Textile braid is to be of cotton, hemp, asbestos, glass, or other equivalent fibre and is to be of strength suitable for the size of the cable. It is to be effectively impregnated with a compound which is resistant to moisture, and flame retarding except where flame-extending cables are permitted by 812.

Dimensions

809 The thickness of insulation and sheath is to be generally in accordance with Tables M 8.2 and M 8.3.

The cables may be used in circuits in which the voltage between a conductor and the hull of the ship does not exceed the voltage at the head of the appropriate Table. In an insulated system the voltage between any conductor and the hull of the ship is assumed to be equal to the voltage between lines.

250 V cables may be used for any conductor of a three-phase, 440 V, alternating-current system with star point earthed.

Cables with other dimensions but which comply with a national specification for marine cables may be submitted for consideration.

Choice of Cables

810 The rated voltage of any cable is to be not lower than the nominal voltage of the circuit for which it is used.

Cables exposed to voltage surges associated with highly inductive circuits, e.g., contactor operating circuits for winches, etc., are to be at least 500 V grade.

The rated operating temperature of the insulating material is to be at least 10degC (18degF) higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

Where polyvinylchloride insulation is employed, particular care should be taken to avoid damage to the sheathing during the fitting of watertight bulkhead glands.

Choice of Protective Covering

811 Cables fitted in the following locations:-

Decks exposed to the weather

Bathrooms

Cargo holds

Refrigerated spaces

Machinery spaces

or in any other location where water condensation or harmful vapour (e.g., oil vapour) may be present are to have an impervious sheath. In permanently wet situations metallic sheaths are to be used for cables with hygroscopic insulation.

- 812 All cables are to be of flame-retardant or fireresisting types (see 850) except that flame-extending cables may be used for final circuits only in the following cases:—
- (a) Where cables are installed in metallic conduits having an internal diameter not exceeding 25 mm (1 in) and provided the conduits are mechanically and electrically continuous.
- (b) Bare lead sheathed cable having conductor sections not exceeding 4,5 mm² (0.007 in²).

Current Rating

813 The highest continuous load carried by a cable is not to exceed its current rating. The diversity factor of the individual loads and the duration of the maximum demand may be allowed for in estimating the maximum continuous load and is to be shown on plans submitted for approval.

The voltage drop from the main switchboard busbars to any point in the installation when the cables are carrying maximum current under normal conditions of service, is not to exceed 6 per cent of the nominal voltage.

In assessing the current rating of lighting circuits every lampholder is to be assessed at the maximum load likely to be connected to it, with a minimum of 60 watts, unless the fitting is so constructed as to take only a lamp rated at less than 60 watts.

Cables supplying cargo winches, cranes, windlasses and capstans are to be suitably rated for their duty. Unless the duty is such as to require a longer time rating, cables for winch or crane motors may be half hour rated on the basis of the half hour bhp of the motors. Cables for windlass and capstan motors are to be not less than one hour rated on the basis of the one hour bhp of the motor. In all cases the rating is to be subject to the voltage drop being within the specified limits.

TABLE M 8.2
THICKNESS OF INSULATION

Nominal ere	oss-section		Rubb	er and erlike	P.7	7.C.	Varn	ished Car	mbric	Asbe	stos-Varn	ished Car	nbrie	Min	eral
			250 V.	660 V.	250 V.	660 V.	1100	ν.	3300 V.	250	ν.	660	v.	440 V.	660 V
			Radial	Radial	Radial	Radial	e/e	c/s	c/e; e/s	Radial Cambric	Radial Asbestos	Radial Cambrie	Radial Asbestos	c/c; c/s	e/e; e/
	in.2	mm ²	in.	in.	in.	in.	in. mm	in.	in. mm	in. mm	in. mm	in.	in. mm	in.	in.
1/.044	.0015	1	·030	·055	·025	0,9				·018 0,45	·020 0,5	0,8	0.030	.040	·060
3/-029	.002		-030	.055	.025	.035				.018	*020	.030	•030	1,0	.06
3/-036; 1/-064	-003	1,5	0,8	1,4	0,6	0,9				0,45 018	0,5	0,8	0,8	1,0	1,5
7/-029	-0045	2,5	0,8	1,4	0,6	0,9	-070	.055	ш	0,45	0,5	0,8	0,8	1,0	1,5
7/-036	-007	4	0,9	1,5	0,6	1,0	1,8 ·070	1,4 ·055	39	0,45	0,5	0,8	0,8	1,0	1,5
7/-044	-01	6	0,9	1,5 .060	0,8	1,0	1,8 ·070	1,4		0,45 ·018	0,5	0,8	0,8		1,5
7/-052	.0145	10	.040	.060	.035	.040	.070	.055	.130	.018	.020	.030	-030		.06
7/.064	.0225	10	1,0	1,5	0,9	1,0	1,8	1,4	3,3	0,45	0,5	0,8	0,8		1,5
19/-044	.03	16	1,0	1,5	0,9	1,1	1,8 .070	1,4	3,3 ·130	0,45 ·018	0,5	0,8	0,8		1,5
19/-052	.04	25	4,2 ·050	1,6	1,0	1,3	1,8	1,4	3,3 ·130	0,45	0,5	0,8	0,8		1,5
19/-064	-06	35	1,4	1,6 .065		1,3	1,8	1,4 ·055	3,3	0,45	0,6	0,8	1,2		1,5
10/ 001	00	50	000	1,7		1,4	1.8	1,4	3,3	010	020	0.8	1.2		1.5
19/-083	-1	60		-070		1,4	1,8	1,4	.130			0,8	1,2		1,5
	LLIVE I	70 95		1,8		1,4 1,5	1,8 1,8	1,4 1,4	3,3			0,8	1,2 1,2		1,5
37/.072	-15	120		2,3		1,6	1,8	·055 1,4	3,3			0,8	1,9		1,5
$37/\cdot 083$.2			·090 2,4		.065	.070	.055	·130 3,3			030	.075 1,9		1,5
37/-093	.25	150		.095		1,6	1,8	1,4	.130			.030	.075		.06
37/-103	+3	185		2,5 ·100		1,9 ·075	1,8 .070	1,4	3,3		4	0,8	1,9		1,5
61/-093	.4	240		2,7		2,0	1,9 ·080	1,5 ·065	3,3 ·130			0,8	1,9		1,5
61/-103	.5	300		3,0 ·120		2,4	2,0	1,6	3,3			0,8	1,9		1,5
91/-103		400		3,2		2,5	2,0	2,0	3,3			0,8	1,9		1,5
31/-103	.75	500		3.3		2,7	2,3	2.0	3.3			0,8	1.9		1.5
127/-103	1.0	625		3,5		2,8	2,5 ·100	2,3	3,3			0,8	1,9		1,5

c/c = between conductors c/s = between conductor and sheath.

Note. Rubber, Rubberlike and P.V.C. thicknesses are the average of a number of measurements. Tolerance on declared values:

Rubber and Rubberlike 5% + 0.13 mm (0.005 in) P.V.C. up to 1.3 mm (0.050 in) 5% + 0.076 mm (0.003 in).

TABLE M 8.3
THICKNESS OF SHEATH

Diameter 1	inder Sheath	Thickness	of Sheath (Average)
Above	Up to and including	Rubber or P.C.P.	P.V.C.	Lead Allo
in.	in. mm ·25 6,0	in. mm ·040 1,0	in. mm ·035 0,9	in. mm ·040 1,0
6,0	12,0	·050 1,3	·045 1,15	·045 1,15
12,0	19,0	·060 1,5	1,4	·055 1,4
19,0	1·0 25,0	.070 1,8	.070 1,8	·065 1,65
1·0 25,0	1·25 31,0	2,0	.080 2,0	·075 1,9
1·25 31,0	1·5 38,0	2,3	2,3	·085 2,15
1·5 38,0	1·75 44,0	·100 2,5	·100 2,5	·095 2,4
1·75 44,0	2·0 51,0	2,8	2,8	·105 2,65
2·0 51,0	2·25 57,0	3,0	3,0	·115 2,9
2·25 57,0	2·5 63,0	3,3	·130 3,3	·125 3,15
2·5 63,0	2·75 70,0	·140 3,5	·140 3,5	·135 3,4
2·75 70,0	3·0 76,0	·150 3,8	3,8	3,7
3·0 76,0	3·25 82,0	·160 4,0	·160 4,0	·155 3,9

Tolerances on declared values:-

P.C.P. 5% + 0.25 mm (0.010 in)P.V.C. Up to and including 1,9 mm (0.075 in) 5% + 0.18 mm (0.007 in)Above 1,9 mm (0.075 in) 5% + 0.25 mm (0.010 in)Lead Alloy 5% + 0.13 mm (0.005 in)

For lead-alloy sheath, if the minimum at a point method of measurement is preferred the thickness of sheath is to be at least the values given above reduced by 0.25 mm (0.010 in)

The following Table M 8.4 gives the maximum permissible continuous-current rating for single- and multi-core cables, except that where a more precise evaluation of current rating has been carried out based on experimental or calculated data, details may be submitted for approval.

Correction Factors for Current Rating

814 (a) Bunching of Cables—Where more than six cables belonging to the same circuit are bunched together a correction factor of 0,85 is to be applied.

- (b) Ambient Temperature—When it is known that the ambient temperature is different from that given in M 106 the correction factors, as shown in Table M 8.5, are to be applied.
- (c) Intermittent Service—Where the load is intermittent the correction factors in Table M 8.6 may be applied for half hour and one hour ratings. In no case is a shorter rating than one half hour rating to be used, whatever the degree of intermittency.

Installation of Cables

- 815 Cable runs are to be, as far as possible, straight and accessible.
- 816 The installation of cables across expansion joints in the ship's structure is to be avoided. Where this is not practicable a loop of cable of length proportional to the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.
- 817 Where a duplicate supply is required the two cables are to follow different routes which are to be as far apart as practicable.
- 818 Cables having insulating materials with different maximum-rated conductor temperatures are not to be bunched together, or, where this is not practicable, the cables are to be operated so that no cable reaches a temperature higher than that permitted for the lowest temperature-rated cable in the group.
- 819 Cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.
- 820 When installing cables the minimum internal radius of bend is to be generally in accordance with:—
 - 6 d for rubber and PVC cables with metal covering
 - 6 d for rubber and PVC cables exceeding 25,4 mm (1 in) diameter and without metal covering
 - 4 d for rubber and PVC cables exceeding 9,5 mm (0.375 in) diameter and without metal covering
 - 8 d for varnished-cambric cables
 - 4 d for mineral-insulated cables (d = overall diameter of cable).

Mechanical Protection

821 Cables exposed to risk of mechanical damage are to be protected by metal channels or casing or enclosed in steel conduit unless the protective covering (e.g., armour or sheath) is sufficient to withstand the possible damage.

CURRENT RATING IN AMPERES

(Based on ambient temperature 45°C)

TABLE M 8.4 (a)—GENERAL PURPOSE RUBBER AND P.V.C.

Nomina	d cross-section		Single core	2 core	3 or 4 core
	in ²	mm ²	Single core	2 0010	3 01 4 0016
1/·044 3/·029	·0015 ·002	1	9 9 11	7 7 9	6 6 7
3/.036; 1/.064	.003	1,5 2,5	12 14 17	10 11 14	8 9 11
7/·029 7/·036	·0045 ·007	4	18 23 25	16 19 21	13 16 17
7/·044 7/·052	·01 ·0145	6	30 31 37	25 26 31	21 22 26
7/.064	-0225	10 16	41 51 54	34 43 45	28 35 37
19/·044 19/·052	·03 ·04	25	60 70 72	51 59 61	42 49 50
19/-064	.06	35 50	86 92 105	73 78 91	60 64 75
19/.083	-1	60 70	120 125 130	100 105 110	84 87 91
37/-072	·15	95 120	160 160 180	135 135 155	110 110 130
37/·083 37/·093	·2 ·25	150	190 210 220	160 180 185	135 145 155
37/-103	-3	185 240	240 250 280	205 210 240	170 175 200
61/-093 61/-103	·4 ·5	300	300 325 D.C. 340 A.C.	255 275 D.C. 290 A.C.	210 225 D.C. 240 A.C.
91/-103	·6 ·75	400	380 375 390 385 445 420	325 320 330 325 375 360	265 265 275 270 310 295
127/·103	1.0	500 625	450 430 520 470 530 480	380 365 440 375 450 405	315 300 360 330 370 335

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TABLE M 8.4 (b)—HEAT RESISTING RUBBER

	Nominal cross-section			2 core	3 or 4 core	
	in ²	mm ²	Single core		0 01 4 0010	
1/.044	.0015		14	11	9	
1/.044	.0015	1	14	11	9	
3/-029	-002		17	- 14	11	
7						
3/.036; 1/.064	.003	1,5	19 21	16 17	13	
3/.030; 1/.004	.003	2,5	25	21	14 17	
		2,0	20	21	14	
7/-029	.0045		27	23	18	
71.000	000	4	32	27	22	
7/.036	-007		35	29	24	
		6	42	35	29	
7/-044	·01		44	37	30	
7/-052	-0145		55	46	38	
		10	58	49	40	
7/.064	.0225		74	62	51	
		16	. 78	66	54	
19/-044	-03		87	74	61	
10/ 011	00	25	100	86	71	
19/.052	.04		105	89	73	
		35	125	105	88	
19/.064	-06	00	135	115	94	
10/ 001	00	50	155	135	110	
		20				
10/.009	-1	_ 60	175	150 155	125	
19/.083	.1	70	185 195	165	130 135	
			100		100	
2077260		95	235	200	160	
37/-072	·15	700	235	200	165	
		120	270	230	190	
37/-083	.2		285 .	240	200	
		150	310	265	215	
37/-093	-25		325	275	225	
		185	355	300	250	
37/-103	-3		365	310	255	
	Se. 11	240	415	355	290	
61/-093	.4		435	370	305	
		300	480	410	335	
61/.103	.5		D.C. 500 A.C.	D.C. 425 A.C.	D.C. 350 A.C	
	.6		560 550	475 465	390 385	
OC. L. CO.		400	570 560	485 475	400 390	
91/-103	-75		640 610	540 520	450 425	
		500	650 620	550 530	455 435	
THE RESERVE OF STREET		625	740 670	630 570	520 470	
and the same of th		040	110 010	000	ULU TI	

TABLE M 8.4 (c)—VARNISHED CAMBRIC, BUTYL

Nominal	cross-section		Single core	2 core	3 or 4 core
	in ²	mm^2	Single core	2 0016	3 01 4 0016
1/·044 3/·029	·0015 ·002	1	15 15 19	12 12 16	10 10 13
3/·036; 1/·064	.003	1,5 2,5	21 23 27	17 19 22	14 16 18
7/·029 7/·036	·0045 ·007	4	29 35 38	24 29 32	20 24 26
7/·044 7/·052	·01 ·0145	6	45 48 60	38 40 51	31 33 42
7/-064	-0225	10 16	63 78 83	53 66 70	44 54 58
19/·044 19/·052	·03 ·04	25	93 110 115	79 93 96	65 77 79
19/-064	-06	35 50	135 145 170	115 120 145	94 100 115
19/-083	-1	60 70	185 195 205	160 165 175	130 135 145
37/-072	·15	95 120	250 255 290	215 215 245	175 180 205
37/·083 37/·093	·2 ·25	150	300 335 345	255 285 295	210 235 240
37/·103	•3	185 240	380 390 445	320 330 380	265 270 310
61/·093 61/·103	·4 ·5	300	465 510 D.C. 530 A.C.	395 435 D.C. 450 A.C.	325 355 D.C. 370 A.C.
91/·103	·6 ·75	400	600 585 610 590 680 640	510 495 520 500 580 540	420 410 425 415 475 450
27/·103	1.0	500 625	690 640 790 680 810 690	590 550 680 580 690 590	485 450 550 480 570 485

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TABLE M 8.4 (d) ASBESTOS-VARNISHED CAMBRIC

Nomina	l cross-section		Single core	2 core	3 or 4 core
	in ²	mm ²			7, 55, 5, 555, 5,
1/·044 3/·029	·0015 ·002	1	16 16 20	13 13 17	11 11 14
3/.036; 1/.064	-003	1,5 2,5	22 25 28	18 21 23	15 17 19
7/·029 7/·036	·0045	4	31 37 41	26 31 34	22 25 28
7/·044 7/·052	·01 ·0145	6	48 51 64	40 43 54	33 35 44
7/-064	•0225	10 16	67 83 89	57 70 75	47 58 62
19/·044 19/·052	·03	25	99 115 120	84 99 105	69 82 94
19/-064	.06	35 50	145 155 180	120 130 155	100 110 125
19/ 083	1 301 41 371	- 60 - 70	200 210 220	170 180 185	140 145 155
37/-072	-15	95 120	270 270 310	220 230 265	190 190 215
37/·083 - 37/·093	·2 ·25	150	320 · 355 370	270 305 315	225 250 260
37/-103	-3	185 240	405 415 475	345 355 405	285 290 330
61/·093 61/·103	·4 ·5	300	495 540 D.C. 570 A.C.	425 465 D.C. 480 A.C.	350 380 D.C. 400 A.C.
91/·103	·6 ·75	400	640 620 650 630 730 680	545 530 550 540 620 580	450 435 455 440 510 475
127/-103	1.0	500, 625	740 690 850 730 870 740	630 590 720 620 740 630	520 480 590 510 610 520

TABLE M 8.4 (e) SILICONE RUBBER, MINERAL

Nominal	cross-section		Single core	2 core	3 or 4 core
	in2	mm ²	Single core	2 0010	3 OF 4 COP6
1/-044	-0015		19	16	13
1/*044	.0019	4		10	
01.000	000	1	20	17	14
3/.029	-002		23	19	16
		1,5	25	21	17
3/.036; 1/.064	-003		27	23	18
		2,5	31	26	21
7/-029	.0045		34	29	23
17 8.75	NEWST .	4	41	35	28
7/.036	-007		44	37	30
17 000					
		6	53	45	37
7/.044	·01		56	47	39
7/.052	·0145	- rail-on	70	59	49
		10	- 73	62	51
7/-064	.0225		93	79	65
		16	99	84	69
19/-044	-03		110	93	77
10/ 011	O	25	130	110	92
19/-052	.04	20	135	115	94
19/1032	.04		100	110	34
		35	165	140	115
19/.064	.06		175	150	125
		50	205	175	145
		60	230	195	160
19/-083	•1	00	240	205	170
10/ 000		70	255	215	175
		95	310	265	215
37/-072	.15	50	315	265	220
31/-012	.19	120	360	305	250
		120	200	909	250
37/-083	-2	1723	380	325	265
		150	420	355	290
37/-093	·25		440	375	310
		185	485	410	340
37/-103	.3	8.75.70	500	425	350
		240	570	485	400
61/.093	.4		600	510	420
0.00		300	660	560	460
31/-103	.5	000	600		485
61/-103	.5		690	590	485

822 Cables in cargo holds and other spaces where there is exceptional risk of mechanical damage are to be suitably protected, even if armoured, unless the steel structure affords adequate protection. See also M 1614.

823 Metal casings for mechanical protection of cables are to be efficiently protected against corrosion.

TABLE M 8.5

Insulation	Correction Factor for Ambient Temperature			
	40°C (104°F)	45°C (113°F)	50°C (122°F)	55°C (131°F)
Rubber or P.V.C. (general purpose)	1,15	1,00	0,82	_
Rubber (heat-resisting quality)	1,08	1,00	0,91	0,82
Varnished Cambric, Butyl	1,07	1,00	0,93	0,85
Asbestos-Varnished Cambric	1,06	1,00	0,94	0,87
Mineral, Silicone Rubber	1,05	1,00	0,95	0,89

Earthing

824 Metal coverings of cables are to be effectively earthed at both ends of the cable, except in final subcircuits where earthing at the supply end only will be considered adequate. This does not necessarily apply to instrumentation cables where single point earthing may be desirable for technical reasons.

825 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings is to be ensured.

826 The lead sheath of lead-sheathed cables is not to be used as the sole means of earthing the non-current carrying parts of items of equipment.

Securing of Cables

827 Cables are to be effectively supported and secured without their coverings being damaged.

828 The distances between supports is to be chosen according to the type of cable, the distances being generally in accordance with Table M 8.7.

829 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection.

TABLE M 8.6

Correction	Half Ho	ur Rating	One Hou	r Rating
Factor	With Metallic Sheath	Without Metallic Sheath	With Metallic Sheath	Without Metallic Sheath
1,0	Up to ·03 in² 20 mm²	Up to ·1 in² 75 mm²	Up to ·1 in² 67 mm²	Up to ·3 in² 230 mm²
1,1	·04-·06 in² 21-40 mm²	·15 in² 76–125 mm²	.·15-·25 in² 68-170 mm²	·4-·6 in² 231-400 mm²
1,15	·1 in² 41–65 mm²	·2-·25 in² 126-180 mm²	·3-·4 in² 171-290 mm²	·75–1·0 in² 401–600 mm²
1,2	66-95 mm²	·3 in² 181–250 mm²	·5-·6 in² 291-430 mm²	
1,25	·15-·2 in² 96-130 mm²	·4 in² 251–320 mm²	·75-1·0 in² 431-600 mm²	
1,3	·25 in² 131–170 mm²	·5-·6 in² 321-400 mm²		
1,35	·3 in² 171–220 mm²	·75 in² 401–500 mm²		
1,4	·4 in² 221–270 mm²			

TABLE M 8.7

External diameter of Cable		Non-Armoured	
Exceeding	Not Exceeding	Cables	Armoured Cables
	0-3 in (7,6 mm)	8 in (20 cm)	10 in (25 cm)
0.3 in (7,6 mm) 0.5 in (12,7 mm)	0.5 in (12,7 mm) 0.75 in (20 mm)	10 in (25 cm) 12 in (30 cm)	12 in (30 cm)
0.75 in (20 mm)	1.25 in (30 mm)	14 in (35 cm)	14 in (35 cm) 16 in (40 cm)
1.25 in (30 mm)	- 20 211 (00 211111)	16 in (40 cm)	18 in (45 cm)

Penetration of Bulkheads and Decks

- 830 Penetration of watertight bulkheads or decks is to be carried out with either individual watertight glands or with packed watertight boxes carrying several cables. However carried out the watertight integrity of the bulkheads or deck is to be maintained. See also 810.
- 831 Cables passing through decks are to be protected by deck tubes or ducts.
- 832 Where cables pass through non-watertight bulkheads or structural steel the holes are to be bushed with lead or other approved material. If the steel is 6 mm (0.25 in) thick, adequately rounded edges may be accepted as the equivalent of bushing.
- 833 Materials used for glands and bushings are to be such that there is no risk of corrosion.
- 834 Where rectangular holes are cut in bulkheads or structural steel the corners are to be radiused.

Installation in Pipes and Conduits

If installed in pipe or conduit the following rules are to be complied with.

- 835 Metal conduit systems are to be earthed and are to be mechanically and electrically continuous across joints. Individual short lengths of conduit need not be earthed.
- 836 The internal radius of bend of pipes and conduit is to be not less than that laid down for cables provided that for pipes exceeding 64 mm (2.5 in) diameter the internal radius of bend is not less than twice the diameter of the pipe.
- 837 The drawing-in factor (ratio of the sum of the cross-sectional areas of the cables to the internal cross-section area of the pipe) is not to exceed 0,4.
- 838 Expansion joints are to be provided where necessary.

839 Where necessary, ventilation openings are to be provided at the highest and lowest points so as to permit air circulation and to prevent accumulation of water.

Where cables are laid in trunks the trunks are to be so constructed as not to afford passage for fire from one between deck or compartment to another.

- 840 High voltage cables, e.g., those used for cold cathode luminous discharge lamps, are not to be installed in metal conduit unless protected by metal sheath or screen.
- 841 Non-metallic ducting or conduit is to be of flameretardant material. PVC conduit is not to be used in refrigerated spaces or on open decks, unless specially approved.

Installation in Refrigerated Spaces

842 Cables installed in refrigerated spaces are to have a watertight or impervious sheath and are to be protected against mechanical damage. If an armoured cable is used the armour, unless galvanized, is to be protected against corrosion by a further moisture-resisting covering.

Cables entering a refrigerated space are to pass directly through the walls or lagging and are to be protected by a tube sealed at each end. Alternatively, the cables may be passed through solid door frames the necessary holes being sealed at each end.

Precautions are to be taken to prevent the placing of hooks round the cable as a casual means of suspension.

Where PVC insulated cables are used in refrigerated spaces a low temperature grade is to be used.

Cables for Alternating Current

- 843 Where it is necessary to use single-core cables for alternating-current circuits rated in excess of 20 A the following rules are to be complied with:—
- (a) Cables are to be either non-armoured or armoured with non-magnetic material.

- (b) If installed in pipe or conduit, cables belonging to the same circuit are to be installed in the same conduit, unless the conduit or pipe is of non-magnetic material.
- (c) Cable clips are to include cables of all phases of a circuit unless the clips are of non-magnetic material.
- (d) When installing two, three or four single-core cables forming respectively single-phase circuits, three-phase circuits or three-phase and neutral circuits the cables are to be in contact with one another, as far as possible. In any event the distance between adjacent cables is not to be greater than 1 diameter.
- (e) If single-core cables, of current rating greater than 250 A are run along a steel bulkhead wherever practicable the cables should be spaced away from the steel.
- (f) Where single core cables of rating exceeding 50 A are used, magnetic material is not to be placed between single-core cables of a group. If these cables pass through steel plates, all cables of the same circuit are to pass through a plate or gland so constructed that there is no magnetic material between the cables and suitable clearance is provided between the cable core and magnetic material. This clearance, wherever practicable, is to be not less than 75 mm (3 in) when the current exceeds 300 A. For currents between 50 A and 300 A the clearance is to be obtained by interpolation.

Cable Ends

844 The ends of all conductors of cross-sectional area greater than 4 mm² (0.0065 in²) are to be fitted with soldering sockets, compression type sockets or mechanical clamps. Corrosive fluxes are not to be used.

Cables having a hygroscopic insulation (e.g., varnished cambric or mineral insulated) are to have their ends sealed against ingress of moisture.

Cables with a supplementary insulating belt beneath the protective sheath are to have additional insulation at those points where the insulation of each core makes or may make contact with earthed metal.

Joints and Branch Circuits

845 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. Terminals or busbars are to be of dimensions adequate for the cable rating.

Testing

846 The following tests are to be made at the manufacturers' works prior to despatch and may be required to be carried out under the supervision of the Surveyors.

All main cable for electric propelling machinery is to be tested in the presence of the Surveyors. See M 1701.

High Voltage Test

847 The test is to be carried out on finished cables with either direct-current or single-phase alternating-current at the manufacturers' discretion. The power available in the test equipment is to be sufficient to maintain in the cable the specified test voltage and the charging current. The voltage is to be applied gradually so as to arrive at the specified figure in approximately one minute. The test voltage is to be applied as follows:—

For cables with metallic covering the test voltage is to be applied between conductor(s) and the metallic covering. For cables with non-metallic impervious sheath the voltage is to be applied between conductor(s) and the water in which the cable is to be immersed for at least one hour before the test. For cables having a non-metallic covering which might be impaired if immersed in water, the voltage is to be applied to samples, at least 1 m (40 in) long, the surface being covered with metal foil. In addition, for multi-core cables the voltage is to be applied in turn between each conductor and all other conductors connected together.

The test voltage in all cases is to be applied for 5 minutes, without failure, the value being in accordance with:—

TABLE M 8.8

Rated Vol	tage of Cable	Test V	Voltage
Above	Up to and including	A.C. Volts	D.C. Volts
	250	1500	3000
250	750	2500	5000
750	1100	3000	6000
1100	3300	10 000	20 000
3300	6600	16 000	32 000

Note.—For mineral insulated cables having a rated voltage up to and including 440 V the test voltage is to be 2000 V alternating current and for voltages above 440 V the test voltage is to be 3000 V alternating current.

Insulation Resistance

848 Immediately after the high voltage test the insulation resistance is to be measured and recorded, using a direct-current voltage of at least 400 V and the measurement being made after electrification for 1 minute. See also M 2002.

Spark Testing

849 Spark testing may be accepted as an alternative to the high voltage and insulation resistance test for cables with rubber or rubber-like insulation. The test is to be made at the core stage except for single core braided and compounded cables which may be tested at the finished stage.

The core or cable is to withstand the test voltage without failure and the speed at which the cable passes through the electrode is to be such that every point is in contact with the electrode for not less than 0,1 sec. Test voltages are given in Table M 8.9.

Flame Extending, Flame Retardant and Fire Resisting

850 A sample of cable 1,2 m (48 in) long is to be clamped vertically in a three-sided enclosure with open top, of size suitable to contain the cable. A bunsen burner of nominal bore 10 mm (0·375 in) fed with ordinary illuminating gas at normal pressure, giving a flame approximately 125 mm (5 in) long with an inner blue cone approximately 40 mm (1·5 in) long, is to be applied to the cable so that the tip of the blue cone touches the cable at approximately 0,4 m (12 in) from its lower end. The burner is to be held at 45° to the vertical and the flame applied for a time

$$t (secs) = 10 + \frac{W}{50}$$

where W = weight of cable sample, in grams.

The application is not to be continuous but in steps of 10 seconds, with 10 seconds interruption between applications.

At the end of this period the burner is to be removed and cables are to be graded as follows:—

- (a) Flame extending when the flame travels along the whole length of the specimen.
- (b) Flame retardant when the flame extinguishes before reaching the top of the specimen.

(c) Fire resisting when, in addition to (b) the specimen is able to withstand after cooling an alternating-current test voltage of twice its rated voltage for 1 minute.

Note.—To ensure correct heat in the gas flame a bare copper wire 0.7 mm (0.028 in) diameter and of length 100 mm (4 in) is to be inserted horizontally in the flame and 50 mm (2 in) above the top of the burner, so that the free end of the wire is vertically above the edge of the burner on the side of the burner remote from the supported end of the wire. If the wire takes more than 6 seconds to melt then the flame is not hot enough for the test.

Other tests which are the equivalent of the above may be submitted for consideration.

Quality of Materials

851 The quality of materials is to be in accordance with the recommendations of I.E.C. Publication 92.

Alternative requirements of National Standards will be considered.

Section 9

TRANSFORMERS

901 The following Rules apply to all transformers for general use rated from 1 kVA to 1000 kVA inclusive and suitable for operating over an input voltage range up to 3300 volts line to line.

Transformers outside these limits will be specially considered.

Construction

902 Transformers except those for motor starting are to be double wound.

Liquid Cooled Transformers

903 Proposals for the use of liquid cooled transformers will be specially considered.

Number and Rating of Transformers

904 Where essential services are supplied the number and ratings of transformers are to be sufficient to ensure the operation of essential services even when one transformer is out of service.

TABLE M 8.9

Rated Voltage of	Conductor Sectional Area		Test Voltage	
Cable V	Above	Up to and including	(r.m.s.) kV	
250	·0225 in² (16 mm²) ·04 in² (25 mm²)	·0225 in² (16 mm²) ·04 in² (25 mm²)	6 8 10	
660	·04 in² (25 mm²)	·04 in² (25 mm²)	10 12	

Regulation

905 The inherent regulation at 0,8 power factor is not to exceed 5 per cent.

Regulation of the complete system is to comply with M 813.

Temperature Rise

906 The temperature rise of windings of dry type transformers above the ambient temperatures given in M 106, when measured by resistance, during continuous operation at the maximum rating is not to exceed:-

> Class A 50°C Class E 60°C

Class B 70°C

Proposals to use Class H or Class C insulation will be specially considered.

Short-Circuit

907 All transformers are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding for 2 secs.

Tests

908 The following tests are to be carried out on all transformers at the manufacturers' works, and a certificate of tests issued by the manufacturer.

HIGH VOLTAGE TEST

(a) The voltage is to be applied to each winding in turn, between the winding under test and the remaining windings, core, frame and tank or casing connected together and to earth.

The test is to be made with 1 kV a.c. plus twice the highest voltage between lines with a minimum of 2.5 kV at any frequency between 25 c/s and 100 c/s and maintained for 1 minute without failure.

INDUCED HIGH VOLTAGE TEST

(b) To test between turns, coils and terminals an a.c. voltage is to be applied between the above parts corresponding to twice the voltage appearing between these parts when rated voltage is applied to the terminals. The duration of the test is to be 1 minute for any test frequency up to and including twice the rated frequency.

INSULATION RESISTANCE

(c) The insulation resistance of each winding in turn to all the other windings, core, frame and tank or casing connected together and to earth is to be measured and recorded together with the temperature of the transformer at the time of the test.

TEMPERATURE RISE

(d) One transformer of each size and type is to be given a temperature rise test.

Section 10

LIGHTING

1001 Lighting which is essential for the safety and the working of the ship is to comply with the following Rules:-

The voltage of tungsten filament lampholders is not to exceed:-

B 22

E 10

250 V

24 V

BAYONET FITTING Normal

Small (single contact)	B 158	130 V
Small (double contact)	B 15d	130 V
Screw Fitting		
Goliath	E 40	250 V
Medium	E 27	250 V
Small	E 14	250 V

Lamps are to be in accordance with the following:-

B 22 up to 200 W

E 27 up to 200 W

E 40 no limit

Miniature

Lampholders are to be constructed of flame-retarding and non-hygroscopic material. All metal parts are to be of robust construction. Goliath lampholders are to be provided with means for locking the lamp in the holder. The temperature of cable connections is not to exceed the maximum conductor temperature permitted for the cable given in M 802.

Fluorescent Lighting

1002 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. In ships for unrestricted service they are to be capable of operating at the ambient temperatures given in M 106.

Capacitors of 0,5 microfarads and above are to be provided with a means of prompt discharge on disconnection of the supply.

Inductors and high reactance transformers are to be installed as close as practicable to the associated discharge lamp.

1003 Where cold cathode luminous discharge lamps of normal operating voltage above 250 V are used a warning notice calling attention to the voltage is to be displayed at points of access to the lamps and where otherwise necessary.

1004 Emergency lighting is to be fitted in accordance with M 111.

Section 11

ACCESSORIES

Enclosures

1101 Enclosures are to be of metal or of flame-retardant insulating materials.

Inspection and Draw Boxes

1102 If metal conduit systems are used inspection and draw boxes are to be of metal and are to be in rigid electrical and mechanical connection with the conduits.

Socket Outlets and Plugs

1103 Where it is necessary to earth the non-current-carrying parts of portable or transportable equipment an effective means of earthing is to be provided at the socket outlet.

On weather decks, galleys, laundries, machinery spaces and all wet situations, socket outlets and plugs are to be effectively shielded against rain or spray and are to be provided with means of maintaining this quality after removal of the plug.

The temperature rise on the live parts of socket outlets and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

All socket outlets of current rating 15 A or more are to be provided with a switch.

Section 12

HEATING AND COOKING EQUIPMENT

1201 Heaters are to be so constructed, installed and protected that clothing, bedding and other flammable material cannot come in contact with them in such a manner as to cause risk of fire. There is to be no excessive heating of adjacent bulkheads or decks.

Section 13

BATTERIES

The following Rules apply to permanently installed secondary batteries.

Construction

1301 The cells of all batteries are to be so constructed and secured as to prevent spilling of the electrolyte due to the motion of the ship and to prevent emission of acid or alkaline spray.

Location

1302 Alkaline batteries and lead acid batteries are not to be installed in the same compartment.

Large batteries are to be installed in a space assigned to the batteries only or alternatively in a deck box if such a space is not available.

Engine starter batteries are to be located as close as practicable to the engine(s) served. If such batteries cannot be accommodated in the battery room they are to be installed so that adequate ventilation is ensured.

Lining of Compartments

1303 Where acid is used as the electrolyte a tray of lead, or wood lined with lead is to be provided below the cells. Alternatively, the deck below the cells is to be protected with lead or other acid-resisting material so as effectually to prevent any acid from lodging in contact with the ship's structure.

The interiors of all battery compartments including shelves are to be painted with corrosion-resistant paint.

Equipment

1304 Switches, fuses and other electrical equipment liable to cause an arc are not to be fitted in battery compartments.

Supports

1305 Batteries are to be so arranged that each cell or crate of cells is accessible from the top and at least one side. Cells or crates are to be carried on non-absorbent insulating supports. Similar insulators are to be fitted to prevent any movement of cells arising from the motion of the ship.

Ventilation

1306 Battery compartments are to be ventilated by an independent ventilating system.

Natural ventilation may be employed if ducts can be run directly from the top of the compartment to the open air with no part of the duct more than 45° from the vertical. If natural ventilation is impracticable mechanical ventilation is to be provided. Interior surfaces of ducts and fans are to be painted with corrosion-resistant paint. Fan motors are not to be located in the air stream.

All openings through the battery compartment bulkheads or decks, other than ventilation openings are to be effectively sealed to reduce the possibility of escape of gas from the battery compartment, into the ship.

Where practicable, battery lockers are to be ventilated similarly to battery compartments.

Deck boxes are to be adequately ventilated and means provided to prevent ingress of water.

Size of Batteries and Charging Facilities

1307 Where batteries are used for starting main engines at least two batteries are to be fitted of such combined size that H 611 is complied with.

Adequate charging facilities are to be provided and where batteries are charged from line voltage, by means of a series resistor, protection against reversal of current is to be provided when the charging voltage is 20 per cent of line voltage or higher.

In d.c. systems means are to be provided to isolate the batteries from the low voltage system when being charged from a higher voltage system.

Protection

1308 Batteries, except starter batteries, are to be protected against short-circuit by a fuse in each insulated conductor or a multi-pole circuit-breaker at a position adjacent to the battery compartment.

1309 A permanent notice is to be fitted to all battery compartments prohibiting naked lights and smoking.

Section 14

INTERNAL COMMUNICATIONS

1401 Where a communication circuit takes its supply direct from power or lighting circuits and in other cases where the voltage of supply exceeds 50 V a.c. or 60 V d.c. all equipment is to be in accordance with the Rules for power and lighting circuits.

1402 Cables are to be fitted in a similar manner to cables installed for lighting and power, but are to be segregated from the latter unless either the lighting and power cables or the communication cables are metal sheathed, or non-metallic impervious sheathed.

1403 Communication circuits other than those supplied from primary batteries are to be protected against overload and short-circuit.

Passenger Alarms

1404 In all passenger ships, except those engaged on short international voyages, electrically operated alarms, for summoning passengers to muster stations are to be fitted. They are to be operable from the bridge.

Steering Gear

1405 Means of communication are to be fitted to enable orders to be transmitted from the bridge to the alternative steering station required by D 2306.

Section 15

SEMI-CONDUCTOR RECTIFIERS FOR POWER

1501 Rectifier stacks are to be so arranged that they may be removed from equipment without dismantling the complete unit.

1502 Where forced cooling is provided the apparatus is to be so arranged that the rectifier cannot remain loaded unless effective cooling is maintained.

1503 When necessary, means are to be provided to guard against d.c. voltage rise due to regenerated power.

1504 When operated in parallel with other sources of d.c. power load sharing is to be such that under normal conditions overloading of any unit does not occur and the combination of paralleled equipment is stable.

1505 Fungus protection of the mercury type is not to be used in the vicinity of selenium rectifiers.

1506 Monocrystalline rectifiers such as germanium and silicon are to be capable of withstanding the effects of transient over-voltages coming from the ship's network.

Section 16

SPECIAL REQUIREMENTS FOR OIL TANKERS AND SHIPS INTENDED FOR THE CARRIAGE IN BULK OF LIQUID CARGOES HAVING A FLASH POINT BELOW 60°C (140°F) (CLOSED CUP TEST)

Generation and Distribution

1601 The following generation and distribution systems only are to be used:—

Two-wire insulated for d.c. and single-phase a.c.

Three-wire insulated for three-phase a.c.

1602 No current-carrying part of the distribution system is to be earthed other than through an earth indicating device or capacitors used for radio interference suppression.

Equipment in Dangerous Spaces

1603 No electrical equipment or wiring, other than that certified intrinsically safe in respect of the gases and vapours involved (see M 109) is to be installed in any space where flammable or explosive vapour may normally be expected to accumulate such as:—

Cargo oil tanks.

Cofferdams adjoining cargo oil tanks.

Cargo pump rooms.

Enclosed spaces immediately above cargo tank crowns (e.g., between decks).

Enclosed spaces, other than cofferdams, adjacent to, and below, the top of a cargo oil tank.

On open deck within 3 m (10 ft) of any oil tank outlet or vapour outlet.

except as detailed in 1604 to 1609.

- 1604 In enclosed spaces immediately above cargo tank crowns lighting fittings only are to be installed and they are to be of flameproof type. The switches controlling such fittings are to be double-pole and are to be located in a safe place. Through runs of cable are permitted.
- 1605 Electrical equipment additional to the lighting fittings referred to in 1604 above may be installed in between deck spaces immediately above cargo tank crowns provided that:—
- (a) Such equipment is housed in a suitably ventilated compartment having access solely from the deck above, and of which the floor is separated from the cargo oil tanks by a cofferdam, and the boundaries are gastight with respect to the cofferdam and the between deck space.
- (b) Cables are supported clear of the gastight boundaries of the compartment. Plans showing the construction of the compartment, the electrical apparatus to be housed therein and the provisions for ventilation are to be submitted.
- 1606 In positions on open deck and within a distance of 3 m (10 ft) from cargo tank hatches, sight ports, tank cleaning openings, ullage openings, sounding pipes, cargo vapour outlets or ventilators, or cargo pump room entrances, electrical equipment is to be flameproof.

- 1607 Hull fittings containing the oscillators of electric sounding devices may be installed in a cofferdam or cargo pump room forward of the oil tanks provided that:—
- (a) Such fittings are housed in a gastight enclosure clear of the cargo tank bulkhead.
- (b) The cables to the oscillators are run within the space in heavy gauge galvanized steel pipe with bolted flange joints and led through watertight glands fitted at the external extremity of the pipe.
- 1608 Cargo pump rooms may be lit by one or both of the following methods:—
- (a) By flameproof fittings within the compartment. The lamps are to be arranged on at least two independent circuits controlled by fuses and double-pole switches located in a safe space outside the compartment. The lamps and corresponding switches and fuses are to be suitably labelled for identification purposes. Well glasses and other covers are to be secured by screws or nuts requiring a special key for their removal. The cables are to comply with 1613, protected from mechanical damage and supported clear of bulkheads and deckheads.
- (b) By fittings located in a safe space. Where a safe space is immediately adjacent the cargo pump rooms may be lighted either:—
 - (i) From that safe space through gastight and watertight glazed ports permanently fitted in the bulkhead or deckhead.
 - (ii) Or by lighting fittings which are flameproof relative to the cargo pump room and gastight relative to the safe space and so designed to admit replacement of the lamp from the safe space.
- 1609 Enclosed spaces other than cofferdams adjacent to and below the top of a cargo tank may be lighted in the same manner as cargo pump rooms. The provisions for ventilation are to be submitted for approval. (See D 4010.)

Portable Lamps

1610 Portable lamps other than self-contained battery fed or equivalent lamps of a certified type, in respect of the gases and vapours involved, are not to be used in any dangerous space.

Lighting Fittings

1611 Except in accommodation spaces enclosing cases of lighting fittings are to be of metal or equally durable and non-flammable approved material.

Fuses

1612 Only cartridge-type fuses are to be used.

Cables on Fore and Aft Gangways and in Dangerous Spaces

- 1613 Cables on fore and aft gangways and in dangerous spaces, where permitted, are to be sheathed with one of the following:—
 - (i) Copper sheath (for mineral insulated cable).
 - (ii) Lead sheath plus further mechanical protection, e.g., armour or non-metallic impervious sheath.
 - (iii) Non-metallic impervious sheath plus armour.

Where corrosion may be expected non-metallic impervious sheath, or equivalent protection, is to be applied over steel armour for corrosion protection.

- 1614 Cables installed on deck in way of cargo tanks or on fore and aft gangways are to be protected against mechanical damage. Where pipes are used the total cross-sectional area of the cables contained within a pipe is not to be more than 30 per cent of the internal cross-sectional area of the pipe. Glands are to be fitted at each bulkhead through which the pipes pass, to allow for expansion and the working of the ship. The pipe system is to be drained and ventilated.
- 1615 All cables except mineral-insulated copper sheathed cables installed on deck in way of cargo tanks, or on fore and aft gangways and all pipes containing such cables are to be kept throughout their length at such distance from steam and exhaust pipes as to be substantially free from any heating effect from such pipes. At the bulkhead this distance is to be not less than 450 mm (18 in) from the flanges of steam pipes more than 75 mm (3 in) in diameter, and not less than 300 mm (12 in) from the flanges of steam pipes 75 mm (3 in) or less in diameter.

Flameproof Equipment

1616 Where flameproof equipment is required, effective means of complete isolation located in a safe space is to be provided. Effective provision is to be made to prevent unauthorized operation resulting in restoration of supply while the risk of exposing live conductors exists.

Intrinsically Safe Equipment

1617 Where intrinsically safe equipment is installed the wiring of the circuit is to be physically separated from that of other circuits. Intrinsically safe equipment may be used where flameproof equipment is required by the Rules.

Section 17

ELECTRIC PROPELLING MACHINERY

General

- 1701 All electric propelling machinery including switchgear, control gear, cables, main and auxiliary generators, motors and exciters is to comply with the relevant sections of the Rules and is to be constructed under special survey.
- 1702 Prime movers are to comply with the relevant sections of Chapter H.
- 1703 Armature shafts and other important steel forgings and castings are to comply with the requirements of Chapter Q.
- 1704 The torsional vibration characteristics of the propulsion system are to be submitted as required by H 241 to H 243 as applicable.
- 1705 Cooling water and lubricating oil systems are to comply with E 8 and E 9 where applicable.

General Arrangements

- 1706 Where the arrangements permit a propulsion motor to be connected to generating plant having a continuous rating greater than the motor rating, means are to be provided to limit the continuous input to the motor to a value not exceeding the continuous full load torque for which the motor and shafts are approved.
- 1707 Motors of 500 hp or over and generators of 400 kW or over are to be provided with means for heating the windings to prevent condensation when idle. If steam pipes are used for this purpose the joints are not to be within the machine.

Excitation

1708 Systems dependent on the auxiliary generators for excitation are to be capable of manœuvring and of maintaining power at all times with a fall of 10 per cent excitation voltage at the busbars.

Where motor driven exciters, boosters, balancers or rectifiers are provided for excitation purposes, provision for an alternative supply of excitation is to be made. Where two machines are used each of at least 50 per cent of the required power it will be sufficient to provide one spare machine.

1709 Negative boosters are to be provided with overspeed protection, where necessary.

1710 In d.c. constant pressure systems arrangements for generator and motor excitation are to be such that if the motor excitation circuit is opened by a switch or contactor the generator excitation is simultaneously interrupted or the generator voltage is immediately reduced to zero.

1711 Voltages-No voltage limitations are specified.

Manœuvring Controls

- 1712 When two or more control stations are provided indicating lights are to be located at each control to indicate which station is in control.
- 1713 Where bridge or deck control is employed alternative control in the engine room is to be provided.
- 1714 Suitable interlocks, operating preferably by mechanical means are to be provided to prevent damage to the plant as a result of incorrect switching, such as the opening of switches or contactors not intended to be operated while carrying current.
- 1715 Provision is to be made for the manual operation without undue manual effort, of all manœuvring contactors, switches, field regulators and controllers. Where electric, pneumatic or hydraulic aid is used for normal operation, failure of such aid is not to result in interruption of power to the propeller shaft and any such device is to be capable of purely manual operation without delay. This latter requirement does not apply to bridge control equipment.

Alternative arrangements will be specially considered.

Cables

- 1716 Conductors in circuits essential for manœuvring or maintenance of propelling power are to be stranded having not less than seven strands and shall have a nominal cross sectional area of not less than 2,5 mm² or 0.0045 in².
- 1717 Cables which are connected to the slip rings of synchronous motors are to be suitably insulated for the voltage to which they are subjected during manœuvring.
- 1718 All joints are to be so made as to inhibit corrosion. They are to be arranged and supported in a manner suitable for withstanding the electro-mechanical forces due to short-circuit.

Overload and Short-Circuit Protection

1719 Provision is to be made for protection against severe overloads, and electrical faults likely to result in damage to the plant.

Earth Leakage Detection

1720 The main propulsion circuit is to be provided with means for detecting earth faults. For direct-current equipments exceeding 500 V and for all alternating-current equipments, aural and visual alarms are to be automatically operated on the occurrence of an earth fault, but the operation of such devices is not to interrupt the power supply. A switch may be provided to switch off the aural device, but in such cases the visual alarm shall remain switched on to indicate that the aural device is switched off. Alternative arrangements will be specially considered. If an earth connection is used for operating the detector arrangements then in direct-current systems the earth circuit is to be automatically opened in order to stop the circulation of fault current. In alternating-current systems the fault current is to be interrupted or limited to a safe value.

1721 Earth leakage devices are to be arranged to function for all earth faults exceeding 5 amp. In three-phase star connected alternating-current generators and motors with neutral points earthed, the earth leakage device shall operate on the occurrence of an earth fault in the windings of the machine, subject to the provision that 5 per cent of the coils at the neutral end of each phase may be left unprotected by the device. In high voltage a.c. systems where the capacitive leakage current is high consideration will be given to increasing this figure of 5 per cent.

1722 Excitation circuits are to be provided with lamps, voltmeters or other means to indicate continuously the state of the insulation of the excitation circuits under running conditions.

Discharge Protection

- 1723 For the protection of field windings and cables, means are to be provided for limiting the inducted voltage when the field circuits are opened, or alternatively, the induced voltage, when the field circuits are opened, is to be taken at the nominal design voltage.
- 1724 Where excitation is obtained from the auxiliary busbars means are to be provided to limit the voltage induced at the busbars when the auxiliary circuit-breaker or the distribution circuit-breaker opens.
- 1725 Shunt resistors which are connected across the field circuit of synchronous propulsion motors when they are functioning as asynchronous motors are to be suitably insulated for the voltage induced when reversing and are to be amply rated to allow for inadvertent delay during the reversing operation.

Safety Devices

1726 Where separately driven direct-current generators are connected electrically in series means are to be provided to prevent reversal of the direction of rotation of any of them on the failure of the prime mover.

1727 Where, on stopping or reversing the propeller, the regenerated energy transmitted by the propulsion motor is such as to cause a dangerous increase of speed in the prime mover means are to be provided for suitably absorbing or limiting such energy.

1728 Contactors and switches used for reversing the rotation of the propulsion motors are to be provided with means for forcibly opening them if they should inadvertently remain closed and they are to be so interlocked as to prevent the circuits for ahead and astern being closed simultaneously.

Alarms

1729 An aural alarm device is to be provided for machines having enclosed ventilating systems, arranged to operate in the event of the temperature of the heated air exceeding the predetermined safe value.

Identification

1730 All important circuits, instruments and apparatus are to be clearly labelled for identification.

Section 18

SPECIAL REQUIREMENTS FOR HIGH VOLTAGE SYSTEMS (see M 203)

Note.—High Voltage refers to a marine electrical supply system operating at a voltage in excess of 500 V, 3-phase, a.c.

Introduction

1801 High voltage generation and distribution may be considered appropriate when:—

- (a) The system fault power under normal operating conditions exceeds 50 MVA.
- (b) The capacity of individual generating sets is in excess of 2500 kW.

Generation and Distribution

1802 Arrangements are to be made so that it is possible to split the main H.V. switchboard into at least two independent sections, each supplied by at least one generator. The switchboard sections should preferably be located in separate compartments.

1803 The distribution system is to be such that essential services which are duplicated are supplied from separate sections of the switchboard.

Insulated Neutral Systems

1804 For insulated neutral systems special consideration is to be given to the dielectric strength of all high voltage equipment.

1805 In order to preserve the same standard of insulation as with 500 V equipment and to guard against over-voltages which may arise with the insulated neutral system, the test voltage during the high voltage test is to be not less than 7,5 times line to neutral voltage and is to be applied for not less than one minute.

For rotating machinery this extra high voltage test may be replaced by:—

(i) An interturn test on a sample coil.

and (ii) The normal high voltage test carried out on the completed machine (see M 428).

The interturn test, between adjacent turns which are not connected in parallel, is to be a type test on the particular insulation system used. The test is to be taken between any adjacent effective turns where the greatest voltage is expected in service. The test is to be made on a coil in the fully processed condition, as it would be in the finished winding and the method of making the test and its duration is to be as in M 428 but preferably at the frequency of the ship's system.

The magnitude of the test withstand voltage is to be as given in Table M 18.1.

TABLE M 18.1

Type of Coil	Interturn Test Voltage	
Single stack coils	$\frac{V}{3} + 1000$	
Multi stack coils where adjacent con- ductors in the width stack are connected in parallel	$\frac{V}{3}$ + 1000	
Multi stack coils with zig-zag series connections	$\frac{2V}{3} + 1000$	
Multi stack coils with up/down series connections	V + 1000	

Where V =System line voltage of the supply for which the coil is designed.

Earthed Neutral Systems

1806 When the earthed neutral system of generation and distribution is used, earthing is to be through a resistor. The resistor is to be such that earth fault current is limited to a value which is not greater than full load current of the largest generator on a switchboard section nor less than three times the minimum current required to operate any device protecting against earth faults.

1807 The high voltage test for equipment in an earthed neutral system is to be as required for medium voltage equipment in other sections of this Chapter.

1808 Generator neutrals may be connected in common provided that the third harmonic content of the waveform of each generator does not exceed 5 per cent.

1809 Where a switchboard is split into sections operated independently or where there are separate switchboards, an earthing resistor is to be provided for each section or for each switchboard.

Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

1810 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

1811 All earthing resistors are to be connected to the hull. In order to eliminate possible interference with radio, radar and communication circuits it is recommended that earthing resistors be bonded together on the hull side of the resistors, and that the means of bonding be separate from that provided by the ship's hull.

Protection

1812 In the earthed neutral system generators are to be provided with protection against internal faults. In the insulated neutral system internal fault protection is recommended.

1813 An efficient means of indicating any earth fault in the system is to be fitted. The indicator may be a low reading ammeter operating from a current transformer in the neutral or leakage indicator or equivalent arrangements ensuring rapid automatic isolation.

1814 Any lower voltage system supplied through transformers from the high voltage system is to be earthed or, alternatively, adequate precautions are to be taken to prevent the low voltage system being charged by leakage from the high voltage system.

Cables, Conductors and Terminations

1815 High voltage cables may be installed:-

(a) In the open, e.g., on carrier plating, when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel, or

(b) Contained in earthed metallic ducting or pipe when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that ducts or pipes are electrically continuous and that short lengths of cable are not left unprotected. Other cables are not to be run in the same ducts or pipes as high voltage cables.

1816 Where practicable, high voltage cables are not to be run through accommodation spaces.

1817 High voltage cables are to be segregated as far as practicable from cables operating at lower voltages.

1818 All high voltage cables are to be readily identifiable by suitable marking.

1819 When single core cables are used precautions are to be taken against circulating currents in the sheath or armour and the cables are to be transposed at intervals of about 16 m (50 ft).

1820 All high voltage equipment is to be so designed and located that adequate space is provided to ensure efficient cable terminations.

1821 Wherever practicable all conductors are to be effectively covered with suitable insulating material. In terminal boxes if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating material.

Switchges

1822 All circuit-breakers are to be of the fully with-drawable type.

Machines

1823 A lower limit of 200 hp or kW is recommended for 3 kV machines and 400 hp or kW for 6 kV machines.

Section 19

LIGHTNING CONDUCTORS

General

1901 Lightning conductors are to be fitted to each mast of all wood, composite, and steel ships having wooden masts or topmasts. They need not be fitted to steel ships having steel masts.

Construction

masts, the lightning conductors are to be composed of continuous copper tape and/or rope, having a section not less than 100 mm^2 (0.15 in^2) which are to be riveted with copper rivets or fastened with copper clamps to a suitable copper spike not less than 13 mm (0.5 in) in diameter, projecting at least 150 mm (6 in) above the top of the mast. Where tape is used the lower end of the tape is to terminate at the point at which the shrouds leave the mast, and is to be securely clamped to a copper rope of not less than 13 mm (0.5 in) diameter. This copper rope is to be led down the shrouds and is to be securely clamped to a copper plate not less than 0.2 m^2 (2 ft^2) in area, fixed well below the light waterline and attached to the ship's side in such a manner that it is to be immersed under all conditions of heel.

1903 In wood and composite ships fitted with steel masts, each mast is to be connected to a copper plate in accordance with 1902, the copper rope being securely attached to and in good electrical contact with the mast at or above the point at which the shrouds leave the mast.

1904 In steel ships fitted with wooden masts, the lightning conductors are to be composed of copper tape or rope terminating in a spike, as set forth in 1902. At the lower end this copper tape or rope is to be securely clamped to the nearest metal forming part of the hull of the ship.

1905 Lightning conductors are to be run as straight as possible, and sharp bends in the conductors are to be avoided. All clamps used are to be of brass or copper, preferably of the serrated contact type, and efficiently locked. No connection is to be dependent on a soldered joint.

1906 The resistance of the lightning conductor, measured between the mast head and the position on the earth plate or hull to which the lightning conductor is earthed, is not to exceed 0,02 ohms.

Section 20

TRIALS

General

2001 Before a new installation, or any alteration or addition to an existing installation is put into service the following trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works.

Insulation Resistance

2002 Instruments—Insulation resistance is to be measured using a self-contained instrument such as a direct reading ohmmeter of the generator type applying a voltage of at least 500 V.

Where a circuit incorporates capacitors of more than 2 microfarads total capacitance, a constant-voltage type instrument is to be used to ensure accurate test readings.

(a) Power and Lighting Circuits—The insulation resistance between all insulated poles and earth and, where practicable, between poles is to be at least 1 megohm.

The installation may be sub-divided and appliances may be disconnected if initial tests produce results less than this figure.

(b) Internal Communication Circuits—Circuits operating at 50 V and above are to have an insulation resistance between conductors and between each conductor and earth of at least 1 megohm.

Circuits operating at less than 50 V are to have an insulation resistance of at least 0,33 megohm.

- (c) SWITCHBOARDS, SECTION BOARDS AND DISTRIBUTION BOARDS—The insulation resistance is to be at least 1 megohm when measured between each busbar and earth and between busbars. This test may be made with all circuit-breakers and switches open and all fuse links for pilot lamps, earth fault-indicating lamps, voltmeters, etc., removed and voltage coils temporarily disconnected, where otherwise damage may result.
- (d) GENERATORS AND MOTORS—The insulation resistance of generators and motors, in normal working condition and with all parts in place is to be measured and recorded.

The test should be carried out with the machine hot, if possible. The insulation resistance of generator and motor cables, field windings and control gear is to be at least 1 megohm.

Earth Continuity

2003 Tests are to be made to verify that all earth continuity conductors are effective and that the bonding and earthing of metallic conduit and/or sheathing of cables is effective.

Performance

2004 It is to be demonstrated that the Rules have been complied with in respect of:—

Satisfactory commutation and performance of each generator throughout a run at full rated load.

Temperatures of joints, connections, circuit-breakers and fuses.

The operation of engine governors, synchronizing devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices.

Voltage regulation of every generator when full rated load is suddenly thrown off.

For a.c. and d.c. generators, satisfactory parallel operation and kW load sharing of all generators capable of being operated in parallel at all loads up to normal sea or harbour working load. For a.c. generators satisfactory parallel operation and kVA load sharing of all generators capable of being operated in parallel at all loads up to normal sea or harbour working load.

All essential motors and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously for a sufficient length of time to demonstrate that they are satisfactory.

Propulsion equipment is to be tested under working conditions and operated in the presence of the Surveyors and to their satisfaction. The equipment is to have sufficient power for going astern to secure proper control of the ship in all normal circumstances. In passenger ships the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manœuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trial.

Voltage Drop

2005 Voltage drop is to be measured, where necessary, to verify that this is not excessive. See M 813.

Section 21

SPARE GEAR

2101 The following articles of spare gear, so far as they are applicable, are to be carried. Items used are to be replaced or made good by the Owners as opportunity occurs.

2102 One set of brushes and one set of bearings for one machine for each size of generator and for each size of motor engaged on essential services, such as those indicated below:—

Air compressors for heavy oil engines.

Scavenge blowers.

Air pumps.

Ballast pumps.

Bilge pumps.

Circulating and cooling water pumps.

Condenser circulating pumps.

Extraction pumps.

Feed water pumps.

Fire pumps.

Fuel valve cooling pumps.

Lubricating oil pumps.

Oil fuel pumps and oil fuel burning units.

Cargo refrigerating motors, including compressors, brine pump, circulating pump, fans, etc.

Fans for forced draught to boilers.

Steering gear.

Windlasses.

Ventilating fans for engine room and boiler rooms.

Oil separators.

Steering Gear

2103 For each size of steering gear motor and motorgenerator if no stand-by electrical machine is installed, the following spare gear is required in addition to the spares for motors enumerated above:—

- (i) Direct-current machinery:-
 - 1 spare armature of each size fitted complete with shaft and half coupling.
 - 1 spare field coil of each type fitted.
- (ii) Alternating-current machinery:-
 - 1 spare stator complete of each size fitted.

Fans for Refrigerating Equipment

2104 For electrically-driven air circulating fans the following spare gear will be required, in addition to the spares enumerated in 2102 for each size of motor installed, except where a duplicate fan motor in accordance with N 370 is installed:—

1 motor complete, or

Direct-current machinery:-

I armature complete.

1 complete set of field coils.

1 complete set of brush gear.

1 set of bearings.

Alternating-current machinery:

1 stator complete.

1 set of bearings.

Control Gear

2105 For the starting gear of motors, such as those enumerated in 2102:—

1 set of contacts which are subject to burning or wear.

1 set of springs.

10 per cent of each different resistance element, but at least one of each.

1 of each type of shunt coil used for contactors, relays or low voltage release.

For six or less starters in which these parts are interchangeable it will be sufficient to provide one set of spares for the starter employing the greatest number of parts.

Switchgear and Distribution Boards

2106 For each type of circuit-breaker on each pole:-

1 set of contacts which are subject to burning or wear.

1 set of parts subject to wear.

1 set of springs.

1 shunt trip coil and 1 resistance element, of each kind used.

15 per cent but not less than six of each type of cartridge or other non-renewable fuses.

Rewireable fuse-handles; 5 per cent, with a minimum of one, of each size or type used, provided that not more than 12 need be supplied.

Navigating and Signal Lights

2107 Navigating and signal lights and their pilot lamps for indicating devices:—

1 complete spare set of lamps.

Emergency Lighting

2108 Where supplied from storage batteries of a voltage different from the ship's circuit:—

1 complete spare set of lamps.

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Electric Couplings

2109 For each size of electric coupling used for propulsion purposes, the following is required as a minimum:—

1 complete set of brush gear.

1 field coil of each type fitted.

1 set of brushes for one coupling.

1 gauge for checking the magnetic air gap.

Spares for the control gear and switchgear as above.

Propulsion Equipment

2110 Owing to the varied characteristics of equipment an exact list of spares cannot be specified but the following should be provided as a minimum:—

(a) Generators, Motors and Exciters—One set of bearing bushes, with oil rings, if used, of each size and type for the propulsion generators, motor and exciter.

Two lines of brush holders of each size and type.

One set of carbon brushes for one generator exciter, and one motor.

One shunt field coil of each size and kind used for direct-current generators, exciter and motors.

One set of slip rings for one motor if of the alternatingcurrent type.

(b) SWITCH AND CONTROL GEAR

One set of contacts liable to burning or wear.

One set of springs.

10 per cent of each different resistance element, but at least one of each.

One of each type of shunt wound coil used for contactors, relays, or trip coils.

Two fuse handles of each type and size, or 15 per cent, but not less than six of each type of fuse.

RECOMMENDATIONS FOR ELECTRICAL EQUIPMENT

The following recommendations are for those features of the electrical installation which are not considered to be the concern of classification and therefore are not included in Chapter M. It should be clearly understood that these recommendations are not mandatory and are intended merely for the use of those Shipowners and Shipbuilders who may seek more guidance on equipment standards than is given in the Rules.

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RECOMMENDATIONS FOR ELECTRICAL EQUIPMENT

Section 1

GENERAL

Earthing

Rule 108. The following items do not require to be earthed:—

- (i) Lamp caps.
- (ii) Shades, reflectors and guards supported on lighting fittings constructed of or shrouded in insulating material.
- (iii) Metal parts or screws in, or through, insulating material which are thereby separated from current carrying parts in such a way that they cannot become live or come into contact with earthed parts.
- (iv) Portable appliances having double insulation.
- (v) Bearing housings which are insulated in order to prevent circulation of current in the bearings.
- (vi) Clips for fluorescent lamps.
- (vii) Cable clips.
- (viii) Apparatus supplied at extra low voltage.
- (ix) Fixed apparatus or parts of apparatus which, although not shrouded in insulating material is so guarded that it cannot be touched and cannot come in contact with exposed metal.

Section 2

SYSTEMS OF SUPPLY

It is recommended that in alternating current systems for socket outlets where special precautions against shock are necessary, e.g., portable boiler cleaning tools where the operator works in a confined space and his skin will be damp, the following maximum voltages should be used:—

(i) Supplied direct

55 V

250 V

(ii) Where a safety isolating transformer is used supplying only one socket outlet

Section 4

ROTATING MACHINERY

With the exception of machines for purely domestic purposes such as motors of vacuum cleaners, portable tools and galley equipment it is recommended that all machines comply with the requirements of M 4. Machines for domestic purposes should comply with a national or international standard.

Short-circuit

Sudden short-circuit tests, when required by the purchaser, should be a matter for agreement between purchaser and manufacturer. If carried out they should be made at an initial terminal voltage not greater than the rated voltage of the machine and at rated frequency.

Field Regulation of Direct Current Generators

Rule 417. This requirement will be met if at the conclusion of the full load temperature test, with full load current and normal full load voltage at the terminals when running at full load engine speed, the voltage across the shunt field regulator, with an ambient air temperature of 15°C, is not less than 14 per cent of the terminal voltage of the machine. This makes allowance for the difference in field resistance between average test conditions and the most severe service conditions.

Transient Voltage Response of Alternating Current Service Generators

Rule 423. To meet this requirement it is recommended that one of the following alternatives be applied as determined by the characteristics of the installation, but such a test should not be required if evidence can be produced that a test has been carried out on a similar machine.

(a) When the starting kVa of the motors is 35 per cent or less of the capacity of the generating plant and where a rapid voltage recovery is not required.

With the generator driven at its rated speed at no load and giving its rated voltage under the control of the AVR, the maximum voltage change should not exceed 15 per cent when a current equal to 35 per cent full load current at any power factor between zero and 0,4 lagging is suddenly

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drawn. The voltage should be restored to within 3 per cent of rated voltage in not more than 1,5 seconds.

(b) When the starting kVA of the largest motor or group of motors liable to be started simultaneously exceeds 35 per cent but is less than 60 per cent of the capacity of the generating plant.

With the generator driven at its rated speed at no load and giving its rated voltage under the control of the AVR the maximum voltage change should not exceed 15 per cent when a current equal to 60 per cent full load current at any power factor between zero and 0,4 lagging is suddenly drawn. The voltage should be restored to within 3 per cent of the rated voltage in not more than one second.

(c) When the starting kVA of the largest motor or group of motors liable to be started simultaneously exceeds 60 per cent of the capacity of the generating plant, or when the recovery time of one second is not satisfactory for the operation of special devices supplied by the same generating plant.

A specification of the performance of the generating plant should be agreed between purchaser and manufacturer.

Wattless Load Sharing

Rule 425. This requirement may be otherwise stated:-

"When alternating current generators are operated in parallel, the wattless loads of the individual generating sets should not differ from their proportionate share of the total wattless load by more than 10 per cent of the rated wattless output of the largest machine."

Rule 425 gives a more convenient method of measuring wattless load sharing but other methods can be used, e.g., measurement of the power factor.

Frequency

When running alternating current motors from a shore supply of lower frequency, care should be taken to lower the terminal voltage at the motors in proportion to frequency in order not to overload the motors.

Section 5

DISTRIBUTION

It is recommended that in machinery spaces, large galleys and such spaces as corridors, stairways leading to boat decks and public rooms, lighting should be supplied from at least two final sub-circuits one of which could be the emergency circuit so that failure of one circuit does not reduce the lighting to an inadequate level.

Steering Gear

Where electric power is used for the operation of steering gear it is recommended that failure of supply be indicated by audible and visual alarms in the engine room and/or pilot house.

In any steering gear where electric control only is used it is recommended that the control be duplicated.

Section 6

SWITCHBOARDS, SWITCHGEAR AND PROTECTIVE EQUIPMENT

All main and emergency switchboards should be provided with handrails in front of the panel. Where the switchboard is of the open type the rail should be non-conducting. The platform in front of and behind switchboards should have a non-slip surface.

Where necessary, insulated handrails should be fitted behind switchboards and passageways behind switchboards should be provided with access doors at each end, these to be capable of being opened from the passageway. The doors should bear a prominent and permanent notice giving the maximum voltage.

For voltages between poles or to earth exceeding 250 V direct current or 55 V alternating current, switchboards should be of the dead front type. Where the voltage exceeds 55 V during operation an insulating mat should be provided.

Where an earth indicating system using either two or three lamps is used, the lamps should be of metal filament type each not exceeding 30 W. They should be of the same colour and placed not more than 150 mm (6 in) apart.

For preference tripping systems, the following overcurrent settings are recommended (expressed as a percentage of the rated current of the generator or circuit to be protected):—

Main generator circuit-breaker	150 per cent
Preference tripping relays	110 per cent
Time delays should be established in	accordance with
the nature of the load the following values	being given as an
example:-	

First tripping circuit-breaker	5 sec.
Second tripping circuit-breaker	10 sec.
Third tripping circuit-breaker	15 sec.
Main generator circuit-breaker	20 sec.

For overloads less than 10 per cent protection may

consist of an alarm signal operated by a time delayed relay set to approximately 110 per cent rated current of the generator.

The two-wire circuits of rating exceeding 100 A should be controlled as a minimum in one insulated pole or phase by a switch. Three-wire alternating current circuits rated at more than 60 A should be controlled by a triple-pole linked switch.

The minimum operating current of every circuitbreaker should be not greater than twice the rating of the smallest conductor which it is installed to protect except for motor circuits where short-circuit protection only is required (in these cases three times the cable rating).

The overcurrent setting of a circuit-breaker will depend on individual arrangements and in motor circuits must be matched to the load temperature characteristics of the motor, the following figures being given merely as an example:—

	Overcurrent
Continuously rated circuits	25 per cent
Intermittently rated circuits	50 per cent
Steering gear and emergency circuits	200 per cent

Circuit-breakers, contactors and switches should be so installed that, so far as practicable, their moving parts and associated relays are not live when the circuit-breaker or contactor is in the OFF position.

Circuit-breakers and contactors should be provided with a means of isolation.

In large installations, where fault levels are high, circuit-breakers should be of the power operated type.

In earthed systems of large capacity, protection against internal faults in the generators should be considered.

All generators arranged for parallel operation with one another or with the shore power feeder should be provided with undervoltage release which prevents the closing of the appropriate circuit-breaker until the generator terminal voltage reaches at least 70 per cent of the rated voltage.

The installation of automatic circuit opening devices, other than for short-circuit protection, is not recommended in exciter circuits.

In alternating current systems consideration should be given to the fitting of an automatic trip to main generator circuit-breakers which will open the breaker on loss of excitation.

The fitting of an ammeter in exciter circuits is recommended.

Selection of Fuses

(i) Fuses for steady load circuits, such as heating circuits, should be of current rating at least equal to that of the apparatus. If other overcurrent protection is provided

or if discrimination requires it, a fuse of greater current rating may be necessary.

(ii) Fuses for fluctuating load circuits, such as motor circuits, transformer circuits, lighting circuits and capacitor circuits, should have a time/current characteristic which allows the transient overcurrent to be carried without operation of the fuse. It will sometimes be necessary to select fuses of a current rating greater than that of the circuit.

For motor circuits it will be necessary to obtain particulars of the magnitude and duration of the starting current and to select fuses by referring to the time/current characteristics.

Section 8

CABLES

In large installations where short-circuit currents may be high it is recommended that cables are armoured and in three-phase installations, so far as is practicable, three-core cables carrying the three-phase currents should be employed.

Where these precautions are necessary particular care should be taken with the cable supports especially at the ends of cables.

In 110 V installations where lighting cables may be fully loaded, are bunched together and are installed between wooden panelling or similar locations, it is recommended that the minimum size of conductor be not less than 2.5 mm^2 (0.003 in²).

Section 10

LIGHTING

In bathrooms, galleys, laundries and similar places the parts of a lampholder likely to be touched should be constructed of or shrouded in insulating material and fitted with a protective shield or totally enclosed fittings should be used.

Lighting switches for bathrooms and similar locations should be outside such spaces unless they are of construction suitable for humid conditions.

Lamps which are used near combustible material should be installed in totally enclosed fittings.

Where tubular fluorescent lighting is used, lighting by one or more filament lamps should be provided, especially in compartments containing running machinery. Lamps which are used in spaces liable to contain explosive or flammable materials should be installed in flameproof fittings.

Filament lamps are recommended for emergency lighting.

Live parts of fluorescent lighting installations should be screened with earthed metal or insulating material.

Connections to Lighting Fittings

Due to the reduced physical sizes of lamps in many countries, e.g., 100 W lamps can now be installed in many fittings that previously were designed for 60 W lamps, care must be taken with cable connections so that the maximum conductor temperature is not exceeded. Tests carried out in the past have shown a temperature rise at some lampholder terminals of 80°C and a distance about 16 mm (0.625 in) from the lampholder terminals exhibited a temperature rise of 60°C.

Where cables operate at temperatures in excess of the permitted maximum, deterioration of the insulation occurs with premature failure in service.

Comments on the behaviour of the various classes of insulation are given below:—

(a) RUBBER

Maximum conductor temperature 60°C. At higher temperatures it ages with increasing severity, reducing its life.

(b) POLYVINYL CHLORIDE

Maximum conductor temperature 60°C. At higher temperatures it may flow away from the conductor when under pressure, e.g., clips.

(c) POLYCHLOROPRENE

This is usually associated with rubber when maximum conductor temperature is 60°C. At higher temperatures it absorbs moisture after cooling leading to electrical breakdown.

(d) BUTYL

Maximum conductor temperature 80°C. At 130°C it ages rapidly and may turn into a powder which can fall away from the conductor if subject to vibration or shock.

(e) SILICONE RUBBER

Maximum conductor temperature 150°C and intermittently up to 200°C.

Fittings should be designed so that the maximum permitted temperature for the cable is not exceeded.

Alternatively, high temperature tails (e.g., silicone rubber) should be incorporated in the fitting and led to a terminal block.

Section 11

ACCESSORIES

Where differing distribution systems are used any socket outlets and plugs should be of such design that incorrect connection cannot be made.

In general, socket outlets should not be fitted in bathrooms, lavatories and similar wet places.

In systems at 110 V direct current and above or 55 V alternating current and above socket outlets and plugs should be provided with an earthing contact. This contact should make contact before the live pins when the plug is inserted.

Heating and Cooking Equipment

Electric heating and cooking equipment should be so constructed that parts which must be handled cannot exceed 55°C.

Heating elements should be readily replaceable.

Connections between elements, switches and supply cables should be carried out with terminals.

Connections between elements and between elements and terminals to which insulated cables may be connected, unless self-supporting and rigidly secured in position should be continuously insulated with incombustible material.

Heating elements should be suitably guarded. Live parts of cooking appliances should be protected so that cooking utensils cannot come into contact with them.

Space heaters in cabins, lockers, etc., should be of the convector type. Space heaters should not be installed in spaces where flammable gases might accumulate.

Batteries

Batteries should be located where they are not exposed to excessive heat or extreme cold. Batteries for emergency service, including emergency diesel engine starting should be located above the bulkhead deck. The best operating conditions for batteries are obtained when the working temperature is between 15°C and 27°C. Where practicable the temperature of the electrolyte should not be permitted to exceed 50°C since higher temperatures tend to reduce the life of the battery. Low temperatures may temporarily reduce the capacity of the battery.

Mechanical ventilation of battery rooms should be capable of changing the air in the battery room four or five times per hour.

RECOMMENDATIONS FOR ELECTRICAL EQUIPMENT

Spare Gear

The provision of an insulation tester is recommended.

Section 6

SPECIAL REQUIREMENTS FOR OIL TANKERS

Flameproof and Intrinsically Safe Equipment

It is sometimes stated that flameproof equipment should be permitted in dangerous spaces, e.g., cargo pump rooms, but this cannot be agreed except as stated in M 16.

Flameproof equipment is flameproof when it leaves the manufacturers' works and after a period of service may no longer be flameproof, due to faulty or inadequate maintenance.

Flameproof lighting fittings are permitted in pump rooms, only because many pump rooms are so large that they cannot be adequately lit through glazed ports.

Intrinsically safe equipment and the circuit to which it belongs is to be physically separated from all other circuits. This is because the certificate of intrinsic safety involves both the equipment and its circuit.

Chapter N

REFRIGERATED CARGO INSTALLATIONS

Extract from Chapter B for reference

B 901 On application from Owners, refrigerated cargo installations which comply with Chapter N of the Rules and are favourably reported on by the Surveyors will be assigned an appropriate class in accordance with N 1. Certificates will be issued and the class notation, together with the particulars of the installation, will be entered in the Supplement.

B 902 The class assigned will be retained provided the installation is found to be in a good and efficient condition at the Periodical, Loading Port, and other Surveys set forth in N 8.

B 903 The paragraphs in B 14 regarding Withdrawal of Class and in B 15 regarding Reclassification, apply also to Refrigerated Cargo Installations.

Section 1

GENERAL

Class Notation

101 The class notation assigned will be Lloyd's RMC followed by the minimum temperature(s) approved by the Committee for the installation with the maximum sea temperature stated, e.g., "to maintain temp. 10°F in the lower and 31°F in the upper chamber with sea temperature 85°F maximum."

NOTE.—The temperature at which the cargo is to be carried is not the responsibility of the Society.

102 Installations constructed under the Society's Special Survey in accordance with N 2 to N 6 will be eligible for the distinguishing mark + before the class notation, thus + Lloyd's RMC. In other cases the mark + will not be assigned.

103 In the case of installations designed to reduce the temperature of non-precooled cargoes a mark ‡ will be shown under the class notation in the Appendix to the Register Book and will be included on the certificate as an indication that an installation has been considered by the Society for this duty. A special statement showing the cargo cooling capabilities of such installations, in respect of stated weights and descriptions of cargoes under stated conditions, will be issued on application by the Owners to the Society's Head Office.

Special Cases

104 The Committee will be prepared to give consideration to cases of ships engaged on voyages of short duration, to installations of small capacity, or to other special circumstances. In such cases the class may include a service limitation or other restriction.

Refrigerants

105 These Rules are applicable to the following primary refrigerants:—

Carbon Dioxide

Ammonia

Dichlorodifluoromethane

Monochlorodifluoromethane

Proposals to use other refrigerants will be specially considered on application, but methyl chloride will not be accepted.

NEW INSTALLATIONS

Section 2

SPECIAL SURVEY DURING CONSTRUCTION

201 New installations intended for classification are to be constructed under the Society's Special Survey in accordance with the requirements of N 3 and N 4; tests are to be carried out as specified in N 5, and spare gear is to be supplied as listed in N 6.

Information and Plans to be Submitted

202 The following information and plans are to be forwarded for consideration before construction is commenced:—

- (a) Refrigerating plant—standard data sheet in duplicate. (Copies of this data sheet may be obtained from the Society's local office.)
- (b) Refrigerating plant—detailed specification in triplicate.
 - (c) Insulation—detailed specification in triplicate.
- (d) General arrangement of insulated chambers in elevation and plan. The plans are to be to a scale adequate for the measurement of the external surfaces and the deck

and bulkhead edges. Dimensions and spacing of frames, beams and stiffeners and details of other steel work protruding into the insulation and within the chambers are to be shown. Oil fuel and liquid cargo tanks adjacent to or below the chambers are to be indicated, and whether heating is provided for such tanks. Ventilating and air conditioning trunks and ducts passing through chambers are to be shown. The plans should include a diagram showing the position of the chambers in relation to other parts of the ship if this is not otherwise apparent.

- (e) Detailed plans showing the thickness and methods of attachment of the insulation and linings on all surfaces, including girders, hatch coamings and pillars; details of insulated doors, and hatch, access, bilge and manhole plugs and their frames. Method of attachment of brine or direct expansion grids and meat rails are also to be shown.
- (f) Arrangement of air ducts (including method of cooling spaces within hatch coamings), air coolers, fans and their motors.
- (g) Air cooler defrosting arrangements, other than hot brine circulating systems.
- (h) Arrangement of brine grids including those in way of hatches; and method of construction.
 - (i) Arrangement of chamber thermometers.
 - (j) General arrangement of refrigerating machinery.
 - (k) Brine circuit diagram with particulars of piping.
- (l) Primary refrigerant gas and fiquid circuit diagrams and full particulars of all pressure piping.
 - (m) Sectional arrangement of refrigerant compressors.

Detailed dimensioned plans of :-

- (n) Compressor crank shafts.
- (o) Compressor crank cases where exposed to the refrigerant pressure.
 - (p) Condensers.
 - (q) Evaporators (brine coolers).
 - (r) Air coolers.
 - (s) Oil separators.
 - (t) Liquid receivers.
 - (u) All other pressure vessels.

Note. All the plans listed, and any others which may be specially requested are to be forwarded in triplicate.

- (v) Similar plans are required for refrigerating plant of other designs.
- (w) Where the refrigerating machines are driven by oil engines particulars and plans are to be submitted in accordance with the requirements of G 104.

- (x) Where the refrigerating machines or air cooler fans are driven by steam engines particulars and plans are to be submitted in accordance with G 104.
- (y) Where air cooler or necessary air stirring fans are electrically driven plans of the motors are to be submitted in accordance with M 429.
- (z) Where it is proposed to apply centralized, bridge or automatic controls, a description of the scheme and particulars of the spares to be carried are to be submitted.

Refrigeration required in excess of N 306

203 Refrigeration required in excess of that specified in N 306, which may be necessary for rapid cooling of chambers, or cooling cargoes loaded at temperatures above the carrying temperature, is to be in accordance with a specification approved by the Owners.

Rate of Air Circulation

204 Where refrigeration is effected by forced air circulation over coolers the proposed fan output in each chamber will be considered in relation to the heat to be removed, the nature of the cargo and the service(s) intended.

Where chambers are intended for the additional duties mentioned in 203 the rate of air circulation is to be in accordance with the Owners' requirements.

Subsequent Modifications or Additions

205 Any subsequent modifications or additions to particulars and/or arrangements shown on the approved plans or in the specifications are also to be submitted for approval.

Novel Arrangement and Designs

206 Where the proposed construction of the refrigerating plant or refrigerated chambers is novel in design or involves the use of unusual material, special tests may be required, and a suitable class notation may be assigned when the Committee consider this necessary.

Survey Requirements

207 From the commencement of the construction and installation of the refrigerating plant and of the insulation and fitting out of the cargo chambers, to the testing of the completed installation, the Surveyors are to examine the materials and workmanship and are to indicate at the earliest opportunity and require the rectification of any items not in accordance with the Rules or the approved specifications and plans, or any material, workmanship or arrangement found to be defective or unsatisfactory.

Section 3

REFRIGERATING PLANT

Definition of a Unit

301 A refrigerating unit comprises a prime mover, one or more refrigerating machines (refrigerant gas compressors), one gas condenser—and in the case of a secondary refrigerant, one brine cooler (gas evaporator)—and the fittings necessary to permit independent operation of the unit.

302 If the prime mover of a refrigerating machine is a steam engine with two or more cylinders and each cylinder drives a corresponding compressor, or there is more than one motor similarly arranged, and if each compressor is connected to its own condenser and brine cooler (where fitted), the arrangement is to be regarded as two or more units as the case may be, provided the units can be used separately or in combination.

Note. Condensers or evaporators of the coll-in-casing type need not necessarily be in separate casings.

- 303 Two or more refrigerating machines (or compressors) driven by a single prime mover, or having only one condenser or one brine cooler (where fitted), are to be regarded as one unit.
- 304 Where a refrigerating plant is provided for subcooling the liquid refrigerant, or cooling the condensers of other refrigerating machines, and is not arranged for cooling the cargo spaces independently, it will not be regarded as a unit.
- 305 Where a refrigerating plant is dependent on the main refrigerating units for cooling the condenser or the refrigerant liquid, it will not be regarded as a unit.

Refrigeration to be Provided

- 306 The refrigeration provided is to be capable of efficiently maintaining the minimum temperature(s) under the conditions applicable to the maximum sea temperature for which approval by the Committee is desired and which is to be specified in the class notation (see N 101), when working 24 hours a day with any one of the refrigerating units out of action. It is recommended that a reasonable margin in plant output over maximum load be allowed for possible overall inefficiencies under service conditions.
- 307 Where part of the necessary refrigeration is obtained by the sub-cooling of the liquid refrigerant by other refrigerating plant, one plant supplying such sub-cooling may be considered sufficient provided the refrigerating

units including the stand-by unit are capable of the full duty specified in 306 in the event of the sub-cooling plant being out of action.

- 308 In any case where all the refrigerating units are not connected for use on all the refrigerated cargo chambers the plant serving each chamber is to comply with the requirements of 306.
- 309 The foregoing requirements are based on the assumption that installations will have relatively few refrigerating units each arranged to serve all chambers. In the case of installations having a large number of small units arranged to serve individual chambers, or groups of chambers, the question of reserve plant will be the subject of special consideration.

Number of Refrigerating Units

310 Not less than two complete refrigerating units are to be fitted. Where two units only are fitted the working parts are to be interchangeable.

Stand-by Pumps

- 311 A stand-by gas condenser cooling water pump is to be installed ready for use in addition to the pumps required for the full duty specified in 306. This stand-by pump may be one of the pumps used for other purposes provided it is of adequate capacity and its use on the gas condenser does not interfere with other essential services.
- 312 Where brine is used for refrigerating the cargo chambers a stand-by brine circulating pump is to be installed ready for use in addition to the pumps required for the full duty specified in 306.

Sea Connections

313 Condenser cooling water is to be taken from not less than two sea connections, one of which may be that provided for other purposes, such as the water ballast inlet. It is recommended that one of the sea connections be provided on the port and the other on the starboard side.

Location of Machinery

314 Where ammonia refrigerant is used the refrigerating machinery is to be in an efficiently ventilated compartment isolated from the propelling machinery spaces and shaft tunnels, and living quarters.

Machinery using non-toxic and non-flammable refrig erants will not be subject to restriction on location in general, but proposals to install relatively large plants in propelling machinery spaces will require special consideration.

Chapter N

Prime Movers

315 Where refrigerating plant is electrically driven the motors and their control gear are to comply with the requirements of M 4 and M 7.

316 Where the refrigerating machinery is steam driven the steam engines are to comply with the requirements of Chapters G and H and the exhaust steam is to be led to the main and auxiliary condensers.

317 Where the refrigerating machinery is driven by oil engines the requirements of Chapters G and H are to be carried out.

Motive Power

318 In the case of 315 the electric power is to be taken from at least two generators (see also M 403) and in the case of 316 steam is to be taken from at least two boilers, each capable of the maximum duty without interference with other essential services.

Plant on Ships not classed with the Society

319 In the case of refrigerating installations being constructed under the Society's Special Survey on ships not intended to be classed with this Society, the generator engines and electrical equipment, which supply power to the refrigerating installations, should be constructed in accordance with the requirements of the Classification Society concerned, but such plant is to be examined generally and under working conditions.

Steel Castings

320 Important steel castings are to comply with the requirements of Q 5.

Steel Forgings

321 Crank shafts and other important steel forgings are to comply with the requirements of Q 6.

Dimensions of Crank Shafts

322 Crank shafts of single acting reciprocating refrigerant compressors, of mild steel having a tensile breaking strength of 44–50 kg/mm² (28–32 ton/in²) are to have dimensions not less than those calculated from the following formulæ.

Where crank shafts are proposed to be made of steel of greater strength or of other material, the particulars including the material specification are to be submitted for special consideration. 323 The formulæ are applicable to compressors operating on the normal cycle, with crank shafts having one, two, three or four cranks at equal angles and one cylinder acting on each, and with two or more main bearings.

324 The formulæ are also applicable to compressors, other than $\rm CO_2$ having the crank and cylinder arrangements as shown in Table N 3.1, but in these cases the calculated shaft diameter is to be increased by 5%, 18% and 25% when the angle between cylinders is 90°, 60° and 45° respectively.

TABLE N 3.1

Number of crank pins	Number of cylinders per crank	Angle between cylinders
1 or 2	2	45°, 60° or 90°
3	2	45° or 60°
4	2	45° or 60°
1	3	45°, 60° or 90°
2	3	45° or 60°
3	3	45°
1	4	45° or 60°
2	4	45°

325 The formulæ are not applicable to crank shafts having more than one crank on the same top centre, or to compressors where the cylinders are arranged for supercharging by gas of higher pressure at an intermediate stage of the stroke.

Diameter of Crank Shafts

326

TABLE N 3.2

Refrigerant	Diameter of crank shaft (All dimensions in mm or in)
Carbon Dioxide (CO ₂)	$ \sqrt[3]{\frac{D^2\left(15\frac{ab}{a+b}+1,25S\right)}{12}} $ for gas discharge pressures up to
	105 kg/cm ² (1500 lb/in ²)
Ammonia (NH ₃) Monochlorodi- fluoromethane	$\sqrt[3]{\frac{D^2(2,5ab}{a+b}+0,158)}{\frac{12}{12}}$
(CH Cl F ₂)	for gas discharge pressures up to 17,5 kg/cm ² (250 lb/in ²)
$\begin{array}{c} {\rm Dichlorodiffuoro-} \\ {\rm methane} \\ {\rm (C~C} l_2~{\rm F}_2) \end{array}$	$ \sqrt[3]{\frac{D^2(1.5 \frac{ab}{a+b} + 0.18)}{12}} $
	for gas discharge pressures up to 10,5 kg/cm ² (150 lb/in ²)

where D = cylinder diameter,

S = length of stroke,

a = distance from the inner edge of one bearing to the centreline of the crankpin nearest the centre of the span,

b = distance from the centreline of the same crankpin to the inner edge of the other bearing,

a + b = distance (or span) between the inner edges of adjacent main bearings.

327 Where it is proposed to make solid forged crank shafts of steel having a specified minimum tensile strength greater than 44 kg/mm² (28 ton/in²), but not exceeding 80 kg/mm² (50 ton/in²), the diameter of the crank shaft is not to be less than given by the following formula:—

Diameter of crank shaft = d
$$\times \sqrt[3]{\frac{44}{0.72T + 12.6}}$$
 mm

$$\left(d \times \sqrt[3]{\frac{28}{0.72T + 8}} \text{ in}\right)$$

where d = diameter, in mm (in), of crank shaft made of steel having a specified minimum tensile strength of 44 kg/mm² (28 ton/in²) as required by 326,

T = proposed specified minimum tensile strength in kg/mm² (ton/in²).

Crank Webs

328 Crank webs are to be of the following proportions or of equivalent strength :—

Breadth of web $= 1,33 \times$ calculated shaft diameter Thickness of web adjacent

to a bearing $= 0.56 \times \text{calculated shaft diameter}$ Thickness of intermediate

webs = 0,75×calculated shaft diameter

CAST IRON CRANK SHAFTS

General

329 Where it is proposed to make crank shafts of cast iron, the material specification and the dimensions of the shaft are to be submitted for special consideration.

Material

330 The material specification should state the type of cast iron, the heat treatment, and mechanical properties, including the specified minimum tensile strength appropriate to the section of the crank shaft casting.

331 Any suitable type of high duty cast iron may be used, provided the minimum specified tensile strength is between 32 and 76 kg/mm² (20 and 48 ton/in²). Crank shafts are to be cast at a foundry approved for the production of cast iron crank shafts. (See Q 8).

Crank Shafts

332 The diameter of the crank shaft is not to be less than that given by the following formula:—

$$\begin{array}{c} {\rm Diameter\,of\,crank} = {\rm d} \times \sqrt[3]{\frac{22}{0.3{\rm T}+7.9-\frac{\rm d}{48}}} \ \ {\rm mm} \\ \\ \left({\rm d} \times \sqrt[3]{\frac{14}{0.3{\rm T}\,+\,5\,-\,\frac{\rm d}{3}}} \, {\rm in} \right) \end{array}$$

where Cl = diameter, in mm (in), required by 326 for a steel crank shaft having a tensile strength of 44 kg/mm² (28 ton/in²),

T = specified minimum tensile strength of cast iron in kg/mm² (ton/in²) which is not to be less than 32 kg/mm² (20 ton/in²).

333 Special consideration will be given to crank shafts which have been designed and developed for optimum fatigue strength with cranks of the most favourable shape, and some allowance made for the superior strength thereby obtained. Particulars of any relevant tests or experience should be submitted.

Crank Webs

334 The proportions of the crank webs are to be as stated in 328.

Fillets and Oil Holes

335 Fillets at the junctions of crank webs with crank pins or journals are to be machined to a radius of not less than 5 per cent of the diameter of the crank shaft and are to have a smooth finish.

Oil holes at the surfaces of crank pins and journals are to be rounded to an even contour with a smooth finish.

Crank Shafts for Compressors of Other Designs

336 The particulars of crank shafts for double acting or compound compressors, and for other refrigerants or arrangements, are to be submitted for special consideration.

Maximum Working Pressures

337 The components of primary refrigerant pressure systems including piping, stop valves and headers are to be designed for a maximum working pressure of not less than:—

105 kg/cm² (1500 lb/in²) for carbon dioxide (CO₂)

17,5 kg/cm² (250lb/in²) for ammonia (NH₃) and monochlorodifluoromethane (CH Cl F_2)

10,5 kg/cm² (150lb/in²) for dichlorodifluoromethane (C Cl₂ F₂)

In the case of crank cases which are exposed to the refrigerant pressure the design pressure is to be not less than:—

 14 kg/cm^2 (200 lb/in²) for ammonia and monochloro-difluoromethane

7 kg/cm2 (100 lb/in2) for dichlorodifluoromethane

Crank cases designed for a lower pressure are to be provided with a pressure relief valve arranged to lift at the design pressure and the discharge led to a safe place.

If desired a lower design pressure may be considered for other parts of the low pressure side of the system.

The design pressure for other refrigerants which may be proposed will be considered on application, but as a general guide this will be the saturated vapour pressure at 46°C (115°F).

Refrigerant Pressure Vessels

338 Welded cylindrical pressure vessels which are of steel construction and exposed to the pressure of the refrigerant are to be constructed in accordance with the requirements of J 1 to J 6 so far as applicable and the pressure tests are to comply with 346.

339 Where ammonia is the refrigerant, pressure vessels are to be constructed to not less than Class 2/2 fusion welded requirements.

340 Where pressure vessel shells are made of steel tube the tubes are to comply with the requirements of Q 7 and E 5 so far as applicable, except that the formula for determining the minimum thickness of straight shells as defined in E 512 shall be modified to:—

$$T = \frac{PD}{2f + P} + 0.75 \text{ mm} \quad \left(T = \frac{PD}{2f + P} + 0.03 \text{ in}\right)$$

The pressure tests are to comply with 346.

341 Where ammonia is the refrigerant, pressure vessel shells are not to be manufactured from lap welded pipes.

342 Where pressure vessels are of forged seamless construction, they are to comply with the requirements of J 201 and Q 6 so far as applicable, and the pressure tests are to comply with 346.

343 Where it is proposed to construct pressure vessels of materials other than steel, or not of cylindrical form, full particulars will be required for special consideration.

Pressure Pipes

344 Steel piping for primary refrigerants is to comply with the requirements of E 5, except that a corrosion allowance of 1 mm (0.04 in) be added to the formula in E 512.

Butt welding of pipe lengths in lieu of flanged joints is to be carried out as required in E 5 under the supervision and to the satisfaction of the Surveyors.

Where the pipes are galvanized, a short part at the ends about 100 mm (4 in) long, is either to be left ungalvanized or the galvanizing is to be removed before welding.

345 Where it is proposed to use pipes of materials other than steel, full particulars are to be submitted for consideration.

Pressure Tests

346 The pressure tests as in Table N 3.3 are to be witnessed by the Society's Surveyors at the makers' works. The hydraulic test may be carried out with any suitable liquid. When it is inconvenient to test the large NH_3 (ammonia) condensers and evaporators by submersion in water the shells may be charged with air and gas, and tested by some suitable means. In the case of C Cl_2 F_2 (dichlorodifluoromethane) and CH Cl F_2 (monochlorodifluoromethane) a suitable gas may be used in lieu of air.

Where difficulty may arise in testing components separately, proposals to test more than one component as a unit should be submitted for consideration in cases where the required test pressures are different for the separate components.

Tests after Erection on Board Ship

347 Carbon dioxide systems are to be examined for gas leaks when the system is charged. Ammonia and monochlorodifluoromethane systems are to be tested to a gas or air pressure of not less than 14 kg/cm² (200 lb/in²).

Dichlorodifluoromethane systems are to be tested by a suitable gas to a pressure of not less than 7 kg/cm² (100 lb/in²).

Brine systems are to be tested to a hydraulic pressure of double the working pressure but not less than 3,5 kg/cm² (50 lb/in²). Where the hydraulic test is not reasonably

TABLE N 3.3

		Minimum Test Pressure		
Refriger- ant	Component	Hydraulic	Air*	
		$\frac{\mathrm{kg/em^2}}{(\mathrm{lb/in^2})}$	kg/em ²	
CO2	Components subject to gas pres-			
	sure:— Compressor cylinder blocks, stop valves, condenser and evapo- rator coils, and other compo- nents.	(3000)	105 (1500)	
	Fusion welded and seamless pressure vessels in accordance with 338, 340 and 342.	as per J 445	105 (1500)	
	Pressure piping in accordance with 344.	as per E 523	105 (1500)	
NH3	Components subject to gas pres-			
and CH Cl F ₂	sure:— Compressor cylinders and stop valves. Compressor crank cases	(600) 21	21 (300) 10.5	
	Condenser, evaporator and air	(300) 105	10,5 (150) 35	
	cooler coils.	(1500)	(500)	
	Condenser and evaporator coils or grids welded to headers, and other components.	35 (500)	17,5 (250)	
	Fusion welded and seamless pressure vessels in accordance with 338, 340 and 342.	as per J 445	17,5 (250)	
	Pressure piping in accordance with 344.	as per E 523	17,5 (250)	
C Cl ₂ F ₂	Components subject to gas pressure:—			
	Crank cases.	(200)	10,5 (150)	
	Small machines with cylinders up to 115 mm (4·5 in) dia, where the cylinders and crankcases are	(300)	(200)	
	in one casting. Fusion welded and seamless pressure vessels in accordance with 338, 340 and 342.	as per J 445	10,5 (150)	
	Pressure piping in accordance with 344.	as per E 523	10,5 (150)	
	All other components in the system.	24,5 (350)	(200)	
	Cooling liquid side of refrigerant condensers.	2WP but not less than 1 kg/cm ² (15 lb/in ²)		
Brine	Air cooler coil assembly.	(100)		
	Cast iron casings of refrigerant evaporators.	2WP but not less than		
	Steel casings of refrigerant evaporators on suction side of pump.	1 kg/cm ² (15 lb/in ²) 2 × head pressure but not less than 2 kg/cm ²		
	Steel casings of refrigerant evaporators on discharge side of pump,	(30 lb/in ²) 2WP but not less than 3,5 kg/cm ² (50 lb/in ²)		
	Open casings of brine evaporators.	Filled to		

*Component submerged in water at 32°C (90°F).

possible, sections of brine leads (service pipes) which have to be insulated before the circuits are complete may be tested by an air pressure of 6 kg/cm² (90 lb/in²).

Oil Separators

348 Suitable oil separators with drains are to be provided to the refrigerant lines. If wire gauze is used in the separator it is to be sufficiently robust and supported to prevent disintegration.

Filters (strainers)

349 Suitable filters are to be provided in the refrigerant gas lines to compressors and in the liquid lines to the regulators. Wire gauze in filters is to be sufficiently robust and supported to prevent disintegration. A filter may be combined with the oil separator required by 348.

Refrigerant Driers

350 Driers are to be fitted in monochlorodifluoromethane and dichlorodifluoromethane refrigerant systems, and the arrangement is to be such that the drier can be by-passed, isolated and opened up without interrupting plant operation.

Brine Systems

351 Where brine is the cooling medium it is recommended that the "closed" system with a brine balance tank be adopted in every case.

Safety Devices

352 A pressure relief valve and/or safety disc is to be fitted between each compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. Where the motive power for the compressor does not exceed 10 kW the pressure relief valve and/or safety disc may be omitted.

353 All pressure vessels of refrigerant systems which could become filled with liquid refrigerant and isolated are to be provided with safety discs and relief valves in series, or other approved arrangements, the discharge being led to a safe place above deck.

354 Suitable spring-loaded safety valves are to be provided to the cooling liquid side of condensers and the brine side of evaporators where the pressure from any pump connected could cause a pressure in excess of the maximum working pressure.

Access to Plant

355 The arrangements are to be such that all components of the refrigerating machinery can be readily opened up for inspection or overhaul. Space is to be provided for the withdrawal and renewal of the tubes in "shell and tube" type evaporators (brine coolers) and condensers.

356 Where the coils of "coil-in-casing" type evaporators (brine coolers) and condensers are unwieldy and cannot readily be withdrawn, two suitably arranged inspection holes are to be provided in the top plate, in the sides at about half-height and in the sides at the bottom. The holes are to be as large as practicable and not less than 230 mm×150 mm (9 in×6 in).

Manual Control

357 Where plants are operated by thermostatic refrigerant control, efficient manual controls are also to be provided, and the arrangement is to be such that thermostatic controls can be by-passed and isolated.

As an alternative, duplicate thermostatically operated refrigerant control valves may be fitted, each valve to be capable of the required duty and operable with the other out of action.

Refrigerating Plant of Other Design

358 Particulars of refrigerating plant of designs other than those mentioned in these Rules (e.g., steam jet vacuum refrigeration plants) are to be submitted for special consideration.

Cooling Appliances in Refrigerated Chambers

- 359 Chambers may be refrigerated by pipe grids on the ceiling and sides or by the circulation of air over coolers.
- 360 Refrigeration by pipe grids in the chamber is to be effected by the circulation of brine, except in the case of installations or chambers of very small capacity when the direct expansion of the refrigerant will be considered. The pipe grids in each chamber are to be arranged in not less than two sections. Each section is to be fitted with valves or cocks so that it can be shut off.
- 361 Either brine or the direct expansion of the refrigerant may be employed in the coils of air coolers. The coils are to be arranged in not less than two sections each of which is to be capable of being readily isolated when necessary.
- 362 The brine or direct expansion leads to, and returns from, the cooling appliances in each chamber are preferably to be in duplicate.
- 363 In order to minimise the dehydration of the cargo and the frosting of the cooling elements, it is recommended that the cooling appliances in each chamber should be designed to maintain the required minimum temperature under the maximum difference of not more than 4,5degC (8degF) between the cooling medium and the chamber.
- 364 Where the joints of brine pipes are made by screwed couplings, the pipes, coupling and back nut threads are to be a good fit and the thickness of the pipes at the bottom of the screw thread is to be not less than 2,5 mm (0·1 in).
- 365 Where the joints of air cooler and grid piping are butt welded they are to comply with 344.

- 366 Steel brine and refrigerant piping, grids, joint sleeves and coils within the refrigerated cargo chambers, or where embedded in insulation, or individually insulated are to be galvanized externally. Where such pipes are connected by screwed couplings or by butt welds, the screw threads clear of the couplings or the butt welds and the adjoining ungalvanised portions of the piping, are to be suitably coated and taped after pressure testing to prevent corrosion. The locations of the joints are to be marked on the outside of the insulation.
- 367 Brine tanks and piping should not be galvanized on the brine side. In cases where any parts of the brine system are so treated, the brine cooling and return tanks, if closed, are to be provided with a ventilating pipe or pipes led to the atmosphere in a location where no damage will arise from the gas discharged, and the ventilating pipes are to be fitted with wire gauze diaphragms which can readily be removed. Where the brine tanks are not closed, the compartments in which they are situated are to be efficiently ventilated.
- 368 Means are to be provided for defrosting air coolers.
- 369 Air coolers are to be provided with trays of suitable depth arranged to collect all water condensate. The trays are to be provided with drains at the bottom so that the whole of the condensate can be drained away when the chambers are in service.
- 370 Access arrangements to air cooler fans and fan motors are to be such that both fans and motors may be readily removed for repair or renewal when the chambers are loaded with refrigerated cargo. Access for servicing only is required in cases where duplicate fans and motors, each capable of the full duty, are installed ready for use; this also applies to centrifugal type fans but not to their motors.
- 371 The air circulation system is to be arranged for positive air delivery to, or suction from, all parts of the chamber, including any space within hatch coamings.
- 372 Where it is intended to carry fruit cargoes which may be adversely affected by low temperatures, into sea areas where the temperature may be below the carrying temperature, facilities for heating the chambers are to be provided.

Air Refreshing Arrangements

373 Where chambers are intended for the carriage of gas-generating cargoes, air refreshing appliances are to be provided.

The position of the air inlets is to be carefully selected to minimize the possibility of vitiated air from any source entering the chambers. Each chamber is to be provided with individual inlets and discharges, having airtight closing appliances.

Section 4

CARGO CHAMBERS

Construction

401 Each individual chamber is to be of steel construction throughout and hose-tested for tightness, or tested more thoroughly by gas and air under slight pressure when required by the Owners.

402 At the request of Owners, special consideration will be given to the construction of divisional bulkheads of materials other than steel, between refrigerated cargo chambers where the chambers concerned are intended for cargoes which will not taint or otherwise adversely affect the cargo in any other chamber.

NOTE. Gases given off by one description of fruit may adversely affect other descriptions by promoting rapid ripening.

403 Hatch plugs and their supports, chamber, air cooler and other access doors, tonnage openings, bilge limbers and plugs are to be made as airtight as possible.

404 Ventilators, duets or pipes passing through refrigerated chambers to other compartments are to be made airtight and efficiently insulated. Ventilators to refrigerated spaces, if fitted, are to be provided with airtight closing appliances.

Airtightness of the Bulkheads and Decks

405 Where refrigeration pipes pass through bulk-heads or decks of refrigerated cargo chambers they are not to be in direct contact with the steelwork, the holes through which they pass are to be true and of suitable finish for effectively sealing by the method intended. It is recommended that holes be trepanned and not burnt out. The airtightness of the bulkheads and decks is to be maintained (see also 408 and 413).

Airtightness of Chambers

406 The foregoing paragraphs, 401 to 405, are mainly concerned with infiltration of odours, gases, water vapour and air, which may taint or adversely affect the refrigerated cargo or the insulation, or cause undesirable frosting of cooling equipment. With this object in view it is also recommended that insulation lining, bilge limbers and plugs, hatch plugs, chamber and access doors be constructed of water vapour-resisting material, or covered with such material, and sealed, where exposed to bilges or external conditions.

Insulation

407 Steelwork is to be thoroughly cleaned and coated in accordance with D 3102 and D 3103 and is to be examined for airtightness of fittings before insulation is applied.

Insulating material approved by the Committee is to be used throughout, and the thickness of insulation over all surfaces and the manner in which it is supported are to be in accordance with the approved specification and plans.

The insulation is to be efficiently packed and, where it is of slab form, the joints are to be butted closely together and staggered, unavoidable crevices being filled with insulating material. Bitumen should not be used for filling crevices.

408 Pipes carrying the refrigerating medium are not to be in contact with the steel structure and are to be effectively insulated outside the chambers they serve, except within insulated brine cooler and control rooms (see also 405 and 413).

Cross-references

409 For insulation of oil storage tank tops and bulkheads, see E 345 and E 346.

For pipes in refrigerated spaces, see E 416 to E 418.

For drainage of refrigerated spaces and cooler trays, see E 211 to E 216.

For use of fork lift trucks in refrigerated spaces, see D 418.

Protection of Insulation

410 The insulation in way of the hatchways and about 0,6 m (2 ft) beyond on the tank top and the tunnel top is to be protected with hardwood sheathing about 50 mm (2 in) thick, or to have similar protection.

Access Plugs and Panels

411 Insulated plugs are to be provided in the insulation where required for easy access to the bilges, bilge suction roses, cooler and space drains and tank manhole doors. Removable panels are to be provided for access to tank air and sounding pipes and drains.

It is recommended that, where no air space is provided below the insulation on the tank tops and the floor covering above the insulation is reinforced asphalt, a number of small insulated inspection plugs be fitted for leakage detection.

Where "loose fill" insulation is fitted and lined with metal it is recommended that airtight inspection plates be provided at the top of vertical surfaces to facilitate inspection and making good any settlement.

Fire-resisting Insulation

412 The insulation in way of coal bunkers and of any surfaces exposed to excessive heat is to be of approved fire-resisting material. Where wood grounds are used for supporting insulation, asbestos strips are to be fitted between the wood grounds and the steelwork to which they are attached.

Where pipes carrying the refrigerating medium pass through bunkers the pipes may be packed with granulated cork but there is to be a thick outer covering of fire-resisting material and the whole is to be protected by steel plates which are to be sealed for airtightness.

Watertight Bulkhead Fittings

413 Where cooling pipes pass through watertight deck plating and bulkheads, the pipes are not to be in contact with the steelwork, and the fittings and packings of the glands are to be both fire-resisting and watertight (see also 405 and 408).

Airtightness of Insulation Lining and Air Ducts

414 Air ducts and insulation linings are to be so constructed and fitted that moving air is prevented from entering the insulation. Special care is necessary where cooling pipes, air refreshing ducts, fan supports, etc., protrude through the lining.

Cargo Battens

415 Cargo battens are to be secured to the insulation linings at the sides and bulkheads of chambers and at other vertical surfaces such as large rectangular section pillars, to provide a space for the circulation of air between the surfaces and refrigerated cargo. Cargo battens need not be fitted in way of air ducting, screens and cooler casings. The battens are to be arranged to suit the direction of air flow, and their outer edges are to be chamfered.

Battens should generally be about $50 \text{ mm} \times 50 \text{ mm}$ (2 in $\times 2$ in) spaced approximately 400 mm (16 in) apart, but smaller battens at closer spacing will be considered in conjunction with the air circulation system and the types of cargo to be carried.

416 Cargo battens of not less than 75 mm \times 75 mm (3 in \times 3 in) are to be secured over the tunnel top insulation.

Stiffening of Insulation Linings and Air Ducts

417 Insulation linings and air screens on the sides of chambers are to be suitably stiffened to prevent crushing by cargo, in particular where ship sides are curved inwards

and according to the nature of the cargo, whether general or refrigerated, which the Owners intend to carry in the chambers. Air duct sides or insulation linings which may have to support heavy loads are to be constructed to Owners' requirements.

Galvanizing of Fixtures

418 All steel bolts, nuts, hangers, brackets and fixtures which support or secure cooling appliances, insulation, meat rails, etc., are to be galvanized.

Thermometers

- 419 Thermometers are to be of approved type, number and position in each chamber.
- 420 Thermometer tubes with their flanges and covers are to be insulated from the deck plating, and on weather decks they are to be so arranged that water will not run down the tubes when taking the temperatures.
- 421 The inside diameter of thermometer tubes is to be not less than 50 mm (2 in) and the tubes are not to be in contact with cold decks.
- 422 Where thermometer tubes pass through compartments other than that which they serve, they are to be efficiently insulated.
- 423 When electric remote reading temperature measurement is used in lieu of direct reading thermometers for the cargo chambers or air circulation system, the instruments and equipment are to be of approved type and are to comply with 424 to 430 and N 501.
- 424 Performance is to be satisfactory and accuracy is to be maintained during voltage and frequency fluctuations given in M 105, at all ambient temperatures up to and including those given in M 106, and in addition, construction is to comply with M 107 where applicable.
- 425 The readings of temperature shall be accurate to within $\pm 0.15 \text{degC}$ ($\pm 0.25 \text{degF}$) of the true temperature in the range -3°C to $+3^{\circ}\text{C}$ (27°F to 37°F), and to within $\pm 0.25 \text{degC}$ ($\pm 0.5 \text{degF}$) in other parts of the temperature range. These requirements will apply at all ambient temperatures to which the instrument and connecting parts may normally be exposed in use up to 50°C (122°F), and in the usual conditions of inclination and vibration associated with marine service.

For scale instruments, the scale deflection should not be less than 5 mm/degC or 0.2in/degF with division markings enabling the indication to be estimated within one-tenth of a degree. The range of temperature will normally be between -29° C and $+21^{\circ}$ C (-20° F and $+70^{\circ}$ F).

In the case of instruments having both scales the deflection for the Fahrenheit scale should not be less than $0.2~\rm in/degF$ with the Centigrade scale graduated to correspond.

426 At least two instruments are to be provided for each installation, with the sensing elements so connected that in the event of a failure of any one instrument, at least one sensing element will be operative for each chamber, either in the chamber or in its air circulation system.

Where a data logger is installed and all the sensing elements are connected to this single instrument, at least one sensing element in each chamber or in its circulating air system is to be connected to a separate instrument of approved type. The display of data loggers is to be in digital form or other equally effective visual indication, registering to one-tenth of a degree.

- 427 Where galvanometers are fitted, two are to be provided for each indicating instrument and a checking resistance fitted.
- 428 Where instruments have individual power supply units a spare power unit, e.g., transformers and rectifier or battery is to be provided for each instrument.
- 429 All temperature sensing elements are to be permanently connected, plug and socket connections not normally being acceptable between the elements and the instruments.

Wiring between the sensing elements and the instruments is to be in accordance with Chapter M. All junction boxes are to be provided with cable glands and all connections are to be of a permanent nature, such as soldered or compression type connections.

430 In order to obtain type approval, plans and specifications of the temperature indicating instrument and equipment are to be forwarded for examination. These are to include details of all components, of the sensing elements, leads and sheathing, and of selector switches and junction boxes.

The instrument and equipment are to be constructed in accordance with the approved plans and specifications.

In order to determine the suitability of the instrument and equipment, the Surveyors will examine a typical installation at the Makers and witness appropriate tests to determine that the degree of accuracy complies with 425. The ability of the instrument to withstand vibration, shock and other typical marine service conditions will be given particular attention.

Section 5

TESTS AFTER COMPLETION

Thermometers

501 All thermometers and equipment for measuring chamber and air suction and delivery temperatures are to be installed on board in accordance with the approved plans and the relevant paragraphs of N 4, and the whole installation completed to the satisfaction of the Surveyors.

Each thermometer is to be checked for accuracy by the contractors and a statement giving the readings to the nearest tenth of a degree at the freezing point of water handed to the Surveyors. The Surveyors may use their discretion as to whether check tests are necessary.

In the case of electric remote reading instruments a statement of calibration for each instrument indicating the method employed is to be supplied.

Air Cooler Fan Outputs and Air Circulating Arrangements

502 Air cooler fans are to be tested by the contractors after the air circulating system has been completed and a statement of the results for each chamber handed to the Surveyors. The statement is to show the static pressure, the cubic feet of air circulated per minute, the fan speed and the power consumption. The air circulation arrangements in the chambers are to be checked for distribution.

Refrigeration Test

503 All plant is to be tested under working conditions and the capabilities of the installation checked by a heat balance test.

Before the commencement of the test the Surveyors are to satisfy themselves that the electrical instruments, gauges and thermometers are accurate.

The chambers are to be cooled down to the temperatures required in the class notation, but not necessarily at the balance period. Unless the decks are insulated so that the steel is exposed to the ambient temperature (see D 423) the chamber temperatures are not to be reduced by more than IdegC (2degF) below the notation temperatures except by special arrangement and with the agreement of the Owners and the Builders.

When the chamber balance test temperatures have been reached they are to be maintained constant for a stabilizing period during which heat is removed from the insulation, etc., in the chambers, and thereafter the temperatures maintained constant for a balance period of six hours, or longer if found necessary. To maintain steady balance temperatures compressor speed or power input to the fan motors may be varied, or if necessary compressors may be run on stop-start cycles. Cylinder unloading should be avoided where possible and devices for varying cylinder duty should not be used. All such adjustments and stop-start cycles are to be carefully logged.

- 504 Observations are to be recorded from the beginning of cooling down to the end of the test. In the early stages logging may be at intervals of about four hours, but external temperatures should be logged hourly for the final eighteen hours of the test, and all other relevant temperatures and pressures, speed and power consumption of compressor and fan motors, power consumption of brine and cooling water pumps logged hourly for the final twelve hours of the test.
- 505 Where an installation is to be completed and tested during a period when extremely low external temperatures are probable and a reasonable difference between the external and internal temperatures will not be possible without reducing the chamber temperatures below the level referred to in 503, the case is to be submitted for special consideration.
- 506 In cases where it is reasonable to believe that the refrigerating plant is inefficient an output test on the plant may also be required.

Air Cooler Defrosting Arrangements

507 The air cooler defrosting arrangements are to be tested.

Section 6

SPARE GEAR

- 601 The following spare gear will be required in all cases:—
 - 1 fan impeller of the propeller type of each size used.
 - 1 set of the wearing parts of the crank shaft seals for each compressor where the crank case is subject to the refrigerant pressure.
 - I set of crank shaft coupling bolts of each size
 - 1 set of motor coupling bolts and washers, of each size used.

- 1 compressor piston with piston or connecting rod complete, of each size used.
- 1 complete assembly of each size of compressor suction and delivery valve.
- 1 complete set of packing for CO₂ compressor piston rod glands of each size used.
- 1 set of the working parts, together with packing and piston leathers, for the lubricating oil pump for CO₂ compressor rod glands.
- 1 gas regulator valve of each size used.
- 1 float regulator assembly of each size used.
- 1 set of suction and delivery valves for cooling water, air and brine pumps, of each size used.
- 1 set of driving belts of each size used.
- Sundry lengths and bends of piping together with flanges, couplings and screwing appliances.
- Sundry cocks, valves, flanges and fittings.
- Assorted bolts, nuts, studs, packing and joint rings.
- 5 per cent of the total number of electrical or tube thermometers, but not less than two of each.
- Not less than two standard thermometers of the necessary temperature range.
- 1 spare battery for each electric thermometer indicator fitted.
- 1 hydrometer, where brine is the cooling medium.
- 1 halide lamp leak detector, where dichlorodifluoromethane or monochlorodifluoromethane is the refrigerant.
- 2 safety valve springs of each size used.
- 6 safety discs of each size used.

In cases where approval is given to alternative arrangements under N 104, additional spare gear may be required according to the circumstances of the case.

602 Where steam driven air circulating fans are fitted, the following spare gear will be required:—

For each size used :-

- 1 crank shaft.
- 1 steam piston and rod complete.
- 1 steam cylinder cover.
- 1 set of connecting rod top and bottom end bearing bushes, and bolts complete.

- 603 Where the refrigerating machines are direct driven by steam engines or by oil engines, the spare gear is to be in accordance with Chapter K.
- 604 Where any component of the refrigerating plant is electrically driven the spare gear is to be in accordance with M 2102, and in the case of fan motors, M 2104, except where a duplicate fan motor (see N 370) is installed ready for use.
- 605 It is assumed that the Owners will arrange for the necessary reserve supply of the refrigerant, calcium chloride and oils for the voyage intended.

Section 7

INSTALLATIONS NOT CONSTRUCTED UNDER SURVEY

- 701 When classification is desired for an installation not constructed under the supervision of the Society's Surveyors, application is to be made to the Committee in writing.
- 702 Full particulars and plans are to be forwarded for consideration, together with the particulars of the materials of the crankshafts, pressure vessels and pressure piping. The requirements of N 202 are to be used for guidance in regard to the information required.
- 703 A special examination is to be made at least to the extent required for Subsequent Special Surveys. (See N 849 to N 857.)
- 704 The thickness and material of the insulation, the particulars of the frames, beams, stiffeners and other steel work within the insulation, the air coolers and/or chamber grid piping, the compressors, evaporators and condensers are to be verified, and the particulars of the other components of the refrigerating plant are to be verified so far as practicable.
- 705 The installation is to conform with the requirements of N 2, N 3, N 4 and N 6, so far as applicable.
- 706 A test is to be carried out in accordance with N 503 to N 505, and air circulation arrangements in the chambers are to be checked for air distribution.

Section 8

PERIODICAL AND OTHER SURVEYS

Incidence of Surveys

801 For the retention of the class assigned, installations are to be subjected to the periodical surveys specified in the following paragraphs.

Running Survey

802 A Running Survey as detailed in 815 to 829 is to be held at intervals of twelve months, and as detailed in 830 to 837 at the intervals stated therein.

Where desired by the Owners, Running Surveys may be held at shorter intervals of time.

In special circumstances, the Committee will be prepared to consider postponement of a Running Survey for a period not exceeding two months, provided application is made by the Owners prior to the due date of the survey and provided a Loading Port Survey is carried out as near to this date as possible.

Special Survey

803 A Special Survey as detailed in 839 to 857 is to be held at four-yearly intervals, the first four years after the date of the survey for classification and thereafter four years from the date of the previous Special Survey.

A Special Survey will normally become due at the same time as a Running Survey, but when they do not coincide, the date assigned to the Special Survey will be that of the Running Survey.

Where it is inconvenient for Owners to fulfil the Special Survey requirements at the due date, the Committee will be prepared to consider its postponement, either wholly or in part, for a period not exceeding twelve months from the due date, provided prior application is made by the Owners, and provided the Running Surveys continue to be held at the specified intervals. Any special circumstances which may arise will require to be dealt with as necessary.

Continuous Special Survey of Insulation

804 At the request of Owners, the Committee may agree to the Special Survey requirements of 844 to 846 being carried out on a Continuous Survey basis on ships in which the Continuous Hull Survey system has been accepted. In these cases the insulation in the compartments concerned and the insulation of the refrigerant piping should be exposed or removed as required by the Surveyors, in rotation, with an interval of five years between consecutive examinations of each part.

If the examination during Continuous Surveys reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor.

Survey of Repairs

805 Where any essential repairs and/or renewals are effected to an installation, they are to be carried out under the supervision and to the satisfaction of the Society's Surveyors. Repairs and renewals effected at ports where there is no Surveyor to this Society are to be surveyed by one of the Society's Surveyors at the earliest opportunity.

Alterations and Additions

806 Plans and particulars of any proposed alterations or additions to the refrigerated cargo chambers or the refrigerating plant are to be submitted for approval before the work is put in hand, and the work is to be carried out under the supervision and to the satisfaction of the Society's Surveyors.

Record of Surveys

807 The date following the class notation "Lloyd's RMC" on the certificate indicates the date when the installation was first classed.

The notation "RS with date" indicates the date of the last Running Survey.

The notation "SRMC with date" indicates the date of the last Special Survey.

When the requirements of the Continuous Special Survey and all other requirements of the Special RMC Survey have been completed the notation assigned will be "SRMC (CSI) with date".

The notations when assigned will be recorded in the appropriate section of the Register Book and in the supplements.

Notice of Surveys

808 It is the responsibility of Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time under the supervision of the Society's Surveyors.

It is, however, the normal practice of the Society to give timely notice to Owners when Periodical Surveys of Refrigerated Cargo Installations become due, but the nonreceipt of such notice does not absolve Owners from this responsibility.

Loading Port Survey

809 When a Loading Port Certificate is required by the Owners or their representatives, a survey as detailed in 810 to 814 is to be carried out at the loading port. The certificate is not in respect of the cargo to be loaded or the manner in which it is to be stowed.

In the case of ships engaged on voyages of less than two months duration, a Loading Port Certificate will be considered as valid for two months, provided the cargoes carried are of such a nature as not to damage the insulation or appliances in the insulated chambers, nor to affect by taint or mould the refrigerated cargoes loaded during that period.

810 The chambers are to be examined in an empty state to ascertain that they are clean and free from odour which may adversely affect the cargo to be loaded, that the brine or other refrigerant pipe grids, cooler coils and connections are free from leakage, that the fixed cargo battens on the vertical surfaces are in good order, that cargo gratings or dunnage battens are provided for the floors or decks and that no damage has been sustained to the insulation or its lining prior to the loading of the refrigerated cargo. Any indications of defective insulation not considered to warrant immediate attention should be noted and specially reported.

- 811 The Surveyor is to satisfy himself that all scuppers and bilge suctions draining insulated spaces are in good working order, and that the liquid seals are primed.
- 812 The refrigerating installation is to be examined under working conditions, and the temperatures in the cargo chambers are to be noted.
- 813 If the ship loads at more than one port, one survey only at the first loading port will be required, provided it includes the examination of all the chambers which are to be used for refrigerated cargo during the voyage and general cargo is not subsequently carried in any of the chambers prior to loading the refrigerated cargo.
- 814 If there is no Surveyor to the Society available at the loading port(s), or if none is obtainable from a port within a reasonable distance, the Committee will accept the report of a survey held at the loading port by a Surveyor appointed by Lloyd's Agent; or in any case where there is no Lloyd's Agent, the report of a survey held by a reliable Surveyor, if available; if no such Surveyor is available, a report signed by two competent engineers of the ship will be accepted.

RUNNING SURVEYS

General

815 Whenever practicable, the machinery in use is to be examined under working conditions on the ship's arrival at the port of discharge before the refrigerated cargo is unloaded.

Log books or other records should be examined and any breakdowns or indications of deficiency in the installation are to be noted and reported.

Cargo Chambers

816 The cargo chambers are to be examined throughout.

817 Insulation linings and fastenings on the sides, bulkheads and deckheads are to be examined as far as practicable for condition and airtightness. The removal of parts of the linings, or drilling, is not required unless insulation deficiency is known or suspected, but any indication of dampness or leakage into the insulation from tanks, decks, scuppers or other source is to be investigated.

818 The coverings on deck, tank top and tunnel top insulation are to be examined for condition and shrinkage. Where there is evidence of deterioration or dampness the insulation is to be tested by drilling and parts of the covering removed if found necessary.

819 Air ducting and cooler casings, and the fastenings and supports for ducts, grids and meat rails are to be examined so far as practicable for damage or deterioration.

820 Hatch plugs and supports, patent hatch covers and seals, chamber and access doors and frames, bilge and manhole plugs, air refreshing pipes and their closing appliances are to be examined for condition and airtightness.

821 The bilges are to be cleaned and suction pipes suction roses, sounding pipes and scupper non-return valves examined. The Surveyor should satisfy himself that all scuppers draining the chambers and cooler trays are in good working order.

Air Coolers and Grids

822 Air cooler coils, cooling grids and valves are to be examined. The Surveyor should satisfy himself that sections of the coils or grids are not choked and that the valves are in good working order.

823 Brine refrigerant cooler coils and grids are to be examined whilst under a pressure of 1,5 times the working pressure or 3 kg/cm² (40 lb/in²) whichever is the greater.

824 Primary refrigerant cooler coils and grids are to be examined whilst under the refrigerant pressure prevailing in the system at the time of the survey, with the plant at rest and the regulating valves opened just sufficient to obtain an approximate balance of pressure throughout the system, and to avoid accumulation of liquid in the coils or grids.

Primary Refrigerant Pressure Vessels and Connections

825 The shells of "shell and tube" and "double pipe" type condensers and evaporators, separators, receivers, driers, filters and other pressure vessels, and the coil terminals of "coil in casing" type condensers and evaporators, are to be examined as far as practicable.

In the case of pressure vessels covered by insulation any evidence of dampness or deterioration of the insulation which could lead to external corrosion of the vessels or their connections is to be investigated.

Piping and Headers

826 Primary refrigerant gas and liquid pipes, brine piping, headers, condenser cooling water piping and valves are to be examined as far as practicable.

Where parts of the piping or headers are covered by insulation an examination of the insulation is to be made as in 825.

Thermometers

827 The thermometers for measuring the chamber, air suction, and air delivery temperatures are to be examined and where repairs or renewals are found necessary the thermometers concerned are afterwards to be checked for accuracy.

Each thermometer is to be tested for accuracy at intervals not exceeding the period between Special Surveys, but not necessarily all at one time. The Surveyor may at his discretion accept the results of thermometer tests carried out by a competent staff or contractor.

Note.—In a number of ships, thermometers of a type not approved by the Society have been fitted in addition to those required by N 419; the former need not be examined or tested.

Fans and Fan Motors

828 A general examination is to be made of air cooler fans, their motors, control gear and cables and the insulation resistance measured. The insulation resistance is not to be less than 100 000 ohms, and for the purpose of this test each item may be taken separately. The Surveyor may at his discretion accept the results of tests carried out by a competent staff or contractor.

Generating Plant

829 The generating plant supplying electric power to the refrigerating machinery is to be examined generally with a view to ascertaining that the plant is being efficiently maintained.

In the case of ships not classed with the Society, the Surveyor is to ascertain that periodical examinations of the generating plant continue to be held by the Classification Society concerned.

Compressors

- 830 Each reciprocating compressor, including those provided for sub-cooling the primary refrigerant, is to be opened up at intervals of two years and examined in accordance with (a) and (b) alternately.
- (a) Cylinder bores, valves and seats, glands, relief devices, suction filters and lubricating arrangements are to be examined. Crank case doors are to be removed for a general examination, and crankshaft bearing surfaces exposed if required by the Surveyor.
- (b) In addition to the examination described in (a), pistons, piston rods, connecting rods, and the crank shaft are to be examined. Crank case glands and the lower halves of main bearings need not be exposed if the Surveyor is satisfied as to alignment and wear.
- 831 Alternatively, each compressor may be opened up after each period of 5000 running hours and examined in accordance with 830 (a) and 830 (b) alternately, but the interval between examinations in accordance with 830 (b) is not to exceed four years unless in special circumstances an extension of this period is agreed by the Committee.

Where this system is adopted it will be the Owners' responsibility to maintain a record of the running hours of each compressor, and to ensure that neither periods of 5000 running hours between examinations, nor four years between examinations in accordance with 830 (b), are exceeded.

It will be the Surveyor's responsibilty to examine the records at Running Surveys and to report the number of running hours logged by each compressor since it was last examined.

Where other than reciprocating compressors are fitted, or where there is a programme of replacement instead of surveys on board, other survey arrangements may be necessary. Each case will be given individual consideration.

Condensers

832 The water end covers of "shell and tube" and "double pipe" type condensers are to be removed for examination of the tubes, tubeplates and covers, in rotation,

approximately half the number of condensers to be examined annually so that all are examined in a period of two years.

Where there are several separate installations in a ship, the number of condensers to be examined annually will be specially considered for each case.

Condenser Cooling Water Pumps

833. The working parts of condenser cooling water pumps, including the standby pump which may be used on other services, are to be examined in regular rotation so that all are examined in a period of two years.

If there are two or more stand-by sources of cooling water supply the examination may be extended over a period of four years and is to include at least two stand-by pumps, approximately half the number of pumps to be examined in each two-year period.

Brine and Primary Refrigerant Circulating Pumps

834 The working parts of brine and primary refrigerant pumps are to be examined in rotation so that all are examined in a period of two years.

Prime Movers

835 Where a refrigerating compressor, water, brine or primary refrigerant pump is electrically driven, a general examination is to be made of the motor, control gear and cables and the insulation resistance measured as in 828, at the same time as the compressor or pump is being examined.

Where a compressor or pump is driven by a steam or internal combustion engine, all the working parts of the engine are to be opened up and examined in a similar manner to that specified for compressors in 830, at the same time as the compressor or pump is being examined.

Steam Jet Vacuum Refrigerating Plant

836 Steam jet plant forming the primary refrigerant system is to be examined in rotation at Running Surveys so that all parts, including flash chambers, water spray arrangements, thermo-compressor steam chambers, nozzles, condensers, pumps and ejectors are examined in a period of two years.

Spare Gear

837 The refrigerating plant spare gear is to be checked.

Survey Records

838 A Survey book or other permanent record is to be kept on board the ship to show the date of examination of the various parts. This is to be available to the Surveyor at all times and is to be signed by the Surveyor on the occasion of each survey.

Note.—The Surveyor may ask for additional items to be opened up for examination if considered necessary at any survey.

FIRST SPECIAL SURVEY

- 839 In addition to the requirements for Running Survey as detailed in 815 to 837, the following are to be complied with.
- 840 Where the refrigerating machinery is driven by internal combustion engines and independent air compressors and air receivers exclusive to the refrigerating plant are installed, the working parts of the compressors and their intercoolers, filters, oil separators and safety devices are to be examined. The air receivers with their mountings, valves and safety devices are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to twice the working pressure.
- 841 The Surveyor is to satisfy himself that all pressure relief valves and/or safety discs throughout the refrigerating plant are in good order. No attempt, however, should be made to test primary refrigerant pressure relief valves on board ship.
- 842 In the case of steam jet vacuum refrigerating plants installed for sub-cooling the primary refrigerant liquid, the flash chambers and water spray arrangements, the thermo-compressor steam chambers and nozzles, the condensers, the cooled water circulating, condenser cooling and condensate extraction pumps, and the air pumps or ejectors are to be examined and, if considered necessary, the condensers are to be tested.
- 843 Sufficient insulation is to be stripped from insulated pressure vessels to permit of the condition of the vessels and their connections being ascertained. Care is to be taken that on replacement of the insulation the vapour sealing of the outer covering is made good.
- 844 Sufficient insulation is to be stripped from pipes carrying the refrigerating medium at various points of the system, both outside and inside the chambers, to permit of the condition of the pipes being ascertained. Care is to be taken that on replacement of the insulation the vapour sealing of the outer covering is made good.
- 845 Sufficient air trunking and insulation lining is to be stripped from the chamber overhead and vertical surfaces to permit of the condition of the insulation,

insulation linings, grounds, supports, hangers and fixtures which support the insulation, grids, meat rails, etc., being ascertained. Care is to be taken that on replacement the ducts and linings are sealed against air blowing into the insulation.

- 846 Sufficient tank top insulation is to be stripped to allow the condition of the grounds and inner insulation lining to be ascertained.
- 847 Sea connections to condenser cooling water pumps are to be opened up and examined.
- 848 Steam pipes to steam engines driving refrigerating machinery, and to steam jet vacuum refrigerating plants are to be examined as required by C 11 if the temperature of the steam is over 454°C (850°F).

In the case of installations on unclassed ships, the Surveyors are to ascertain whether the steam pipes have been similarly dealt with by the Classification Society concerned, and if not, arrangements are to be made for the examination and tests in accordance with C 11.

SUBSEQUENT SPECIAL SURVEYS

- 849 In addition to the requirements for First Special Survey as detailed in 839 to 848, the following are to be complied with.
- 850 The coils of gas condensers of the "coil in casing" type are to be examined and tested to a pressure of 17,5 kg/cm² (250 lb/in²) for dichlorodifluoromethane systems, 70 kg/cm² (1000 lb/in²) for ammonia and monochlorodifluoromethane systems, and 140 kg/cm² (2000 lb/in²) for carbon dioxide systems. Where it is impracticable to remove the coils they may be examined and tested in place.
- 851 The coils of evaporators (brine coolers) of the "coil in casing" type are to be examined and tested to a pressure of 14 kg/cm² (200 lb/in²) for dichlorodifluoromethane systems, 35 kg/cm² (500 lb/in²) for ammonia and monochlorodifluoromethane systems, and 105 kg/cm² (1500 lb/in²) for carbon dioxide systems. Where it is impracticable to remove the coils they may be examined and tested in place.
- 852 Gas condensers of the "shell and tube" type, and gas evaporators (brine coolers) of the "shell and tube" type in which the primary refrigerant is in the shell, are to have the water or brine end covers removed and the shell pneumatically tested with the refrigerant or air, or a mixture of inert gas and refrigerant, to a pressure of 7 kg/cm² (100 lb/in²) for dichlorodifluoromethane systems and 14 kg/cm² (200 lb/in²) for ammonia and monochlorodifluoromethane systems.

853 Gas evaporators (brine coolers) of the "shell and tube" type in which the brine is in the shell are to have the primary refrigerant end covers removed and the shell hydraulically tested to twice the design pressure but to not less than 3 kg/cm² (40 lb/in²).

After refitting the end covers the primary refrigerant side is to be pneumatically tested as stated in 852, and an examination made as far as practicable for gas leakage in the shell with the brine connections removed.

- 854 Primary refrigerant liquid sub-cooling coils in flash chambers of steam jet vacuum refrigerating plants are to be examined and tested to the same pressure as that required for condensers in 850.
- 855 Where brine or water is used for sub-cooling the primary refrigerant liquid in heat exchangers of the "shell and tube" type, the heat exchangers are to be examined and tested in the same manner as that required for condensers in 852.

"Double pipe" type heat exchangers are to be examined so far as practicable with the gas piping under the same pressures as that required for condensers in 852 and the water or brine from the outlets is to be tested for gas leakage.

Other types of heat exchangers using brine or water are to be examined and tested at the discretion of the Surveyor according to the design of such equipment.

- 856 Primary refrigerant chamber grids or air cooler coils are to be tested in place to a pressure of 7 kg/cm² (100 lb/in²) for dichlorodifluoromethane, 10,5 kg/cm² (150 lb/in²) for ammonia and monochlorodifluoromethane systems, and 70 kg/cm² (1000 lb/in²) for carbon dioxide systems.
- 857 Steam pipes to steam engines driving refrigerating machinery, and to steam jet vacuum refrigerating plants are to be examined as required by C11.

In the case of installations on unclassed ships, the Surveyors are to ascertain whether the steam pipes have been similarly dealt with by the Classification Society concerned, and if not, arrangements are to be made for the examination and tests in accordance with C 11.

Section 9

REFRIGERATED FREIGHT CONTAINERS WITH SELF-CONTAINED REFRIGERATING UNITS

General

901 Refrigerated freight containers with self-contained refrigerating plant carried on ships and under supervision and maintenance by the ship's staff as refrigera-

ting installations, are eligible for classification. They are to comply with N 1 to N 8 in so far as they are applicable, together with the following paragraphs.

- 902 The Owners' name and an identification number are to be clearly marked on each container.
- 903 Where a container has not been constructed and tested as in the following paragraph 904, it is to be indicated on the container that it is not to be lifted in a loaded condition.
- 904 Where a container has been constructed for lifting in a loaded condition a deflection test of the structure is to be carried out on the container in a loaded condition under the supervision of the Surveyors.

At this test the container is to be lifted with the cargo space loaded with a uniformly distributed load in three successive stages up to 1,25 times the specified maximum cargo load, and the ratio of the deflection to the length of the container is not to be greater than 1 to 1200.

The empty weight of the container and the maximum cargo load are to be clearly indicated on the container.

905 Where a container is intended for carrying stacked with other similar containers, in addition to the lifting test in 904, the container is to be subjected to a downward load test equal to 1,8 times the maximum intended superimposed weight divided equally between the weight-bearing points.

The empty weight of the container, the maximum cargo load and the maximum superimposed stacking load are to be clearly indicated on the container.

- 906 Where a number of identical containers are being built at the same time the lifting test in 904, and if applicable the load test in 905, applied to one in every five containers may be accepted as sufficient.
- 907 Where it is intended to use fork lift trucks in a container, the suitability of the floor for the maximum intended weight of truck and load may require to be tested on one container or on a prototype floor.
- 908 A log book showing the particulars of the refrigeration of the container during each voyage is to be maintained, and this is to be made available to the Surveyor at each of the surveys required by 930.

Where the plant is operated by thermostatic control the intervals during which the machinery is working and at rest should be recorded occasionally, particularly during the period of maximum external temperature conditions of each voyage.

Class Notation

909 The class notation will be in accordance with N 1 except that where the refrigerant condenser is air cooled the class notation shown in N 101 will give the maximum ambient temperature instead of the maximum sea temperature, e.g., "to maintain temp. minus 12°C (10°F) with ambient temp. 40°C (104°F) maximum."

Where the refrigerating machinery is electrically driven and dependent on the ship's generators for power, the class assigned will be subject to suitable electric power being available at all times when the container is loaded with refrigerated cargo.

Special Survey during Construction

910 The requirements of N 2 are to be complied with in so far as they are applicable.

Refrigerating Plant

- 911 The requirements of N 3 are to be complied with in so far as they are applicable, except as modified by the following paragraphs.
- 912 Where two or more refrigerating units supply refrigeration to a container, the plant is to be capable of efficiently maintaining the minimum internal temperature under the maximum external conditions, to be specified in the class notation, when working 24 hours per day with any one of the refrigerating units out of action.
- 913 When one refrigerating unit supplies refrigeration to a container, the unit is to be capable of efficiently maintaining the minimum internal temperature under the maximum external conditions, to be specified in the class notation, when working not more than 18 hours per day.
- 914 Where the refrigerant condenser is air cooled and the maximum gas discharge pressure is above the maxima specified in N 326 and N 337, the design pressure is to be correspondingly increased.
- 915 Where the design pressure is increased in accordance with 914, the test pressures specified in N 346 are to be increased proportionately.
- 916 Where "shell and tube" type evaporators (brine coolers) and condensers can be readily removed, the space for the withdrawal and renewal of tubes in accordance with N 355 will not be required.
- 917 Where the power for the container refrigerating unit on board ship is provided by an internal combustion engine installed with the unit, the container is to be carried on deck.

918 Where an internal combustion engine is installed with the refrigerating unit for use only on land, the container may be carried in a well ventilated space below deck provided that before placing the container on board, the fuel tank is either drained or removed and stored in a safe place on the ship.

Cargo Space

919 When a container is of metal or timber panel construction the joints of the inner lining panels are to be made airtight and the joints of the outer lining panels are to be efficiently vapour sealed on both sides. Where it is not possible to apply the vapour seal on the inside of the outer panel joints the outer surface of the insulation is to be vapour sealed. All the materials used are to be suitable for the temperatures involved and without detriment to the cargoes carried.

Cargo doors, hinges and fastenings are to be of robust construction and the doors airtight.

- 920 Cargo battens or other suitable means are to be provided to ensure adequate space for circulation of air between the cargo and the linings.
- 921 The containers are to comply with the requirements of N 404 and N 405, N 407 and N 408, N 414, N 417 and N 418 in so far as they are applicable.
- 922 Drains of not less than 19 mm (0.75 in) bore are to be provided from the cargo space and air cooler trays, and the drains are to be fitted with means of closure operable from outside the cargo space.
- 923 Thermometers are to be of approved type and position in the cargo space. Where thermometer tubes are provided the method of attachment is also to be approved.

Tests after Completion

924 Each completed container is to be tested in accordance with the requirements of N 5 in so far as they are applicable.

Spare Gear

- 925 Where two or more refrigerating units supply refrigeration to a container, the spare gear to be carried on the ship with container is to be in accordance with N 6 in so far as that Section is applicable.
- 926 Where a single refrigerating unit supplies refrigeration to a container, a complete spare compressor ready for fitting in place is to be carried on board the ship with the container, together with the spare gear required by 925, except those items which are included in the spare compressor.

927 Where a number of containers with identical refrigerating units are carried on a ship, one set of spare gear as required by 925 or 926, whichever is applicable, is to be carried on board for every ten or part of ten containers. This will apply up to a total of twenty containers carried but where the number exceeds this the additional spare gear required will be specially considered.

928 If at any time a group of containers is divided between two or more ships, spare gear as required by the foregoing paragraphs is to be carried on each ship.

Containers not Constructed under Survey

929 The requirements of N 7 are to be complied with in so far as they are applicable, except as amended by this Section.

Periodical and other Surveys

930 For the retention of the class assigned, periodical and other surveys are to be carried out in accordance with N 8 except as modified in the following paragraphs.

Loading Port Surveys

931 The requirements of N 810 and N 812 are to be complied with and, in addition, the Surveyor is to satisfy himself that the container is placed on board in such a position as to provide free access to it by the ship's personnel for servicing the refrigerating plant and noting the temperatures; and, where the refrigerant condenser is air cooled, to allow free flow of fresh air to, and heated air from, the condenser.

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- 932 Generating plant supplying power and the cables and connections to the refrigerating machinery are to be examined generally.
- 933 The Surveyor is also to satisfy himself that the drains from the cargo space and air cooler trays are clear and the closing devices are in order.
- 934 Where an owner desires a Loading Port Survey of a container which is to be loaded with refrigerated cargo ashore instead of on board the ship, the particular circumstances will require to be specially considered.

Running Surveys

935 The requirements of N 815 to N 837 are to be complied with so far as they are applicable. In addition, the cargo space and air cooler drains and their closing appliances are to be examined.

First Special Survey

936 The requirements of N 839 to N 848 are to be complied with so far as they are applicable.

937 Sufficient covering and insulation is to be stripped from the floor of the container to permit the condition of the insulation, grounds and structure to be ascertained.

Subsequent Special Surveys

938 The requirements of N 849 to N 857 are to be complied with so far as they are applicable, and in addition, those of 937.

Chapter P

MATERIALS FOR SHIP CONSTRUCTION

Note: - For list of steel manufacturers see Appendix following Chapter Q.

General

Materials used in the construction and for the equipment of ships are to be manufactured and tested in accordance with the requirements contained in the following Sections of this Chapter:—

Section 1. General requirements for rolled steel products,

, 2. Mild steel for hull structures,

" 3. Higher tensile steel for hull structures,

4. Steel rivet bars and manufactured rivets,

" 5. Steel castings,

6. Steel forgings,

7. Steel anchors,

8. Chain cable and steering chains,

 Steel wire ropes for standing rigging, towlines and mooring ropes,

,, 10. Fibre ropes,

 Approval of electrodes and combinations of consumables for welding in hull construction,

, 12. Aluminium alloy plates, bars and sections,

,, 13. Aluminium alloy rivets,

, 14. Welding of aluminium alloys.

Section 1

GENERAL REQUIREMENTS FOR ROLLED STEEL PRODUCTS

Scope

101 This Section gives general requirements for steel plates, sections, bars, tubes and other hollow sections used in hull construction.

Approval of Works and Method of Manufacture

102 Steel is to be manufactured at works approved by the Committee. A list of approved manufacturers is given in the Appendix at the end of Chapter Q.

The steel is to be made by the open hearth, electric furnace or oxygen processes or by other processes approved by the Committee. An oxygen process is defined as a process in which molten iron contained in a basic lined converter is refined by directing a jet of high purity gaseous oxygen onto the surface of the hot metal.

The steel making practice is to be such as to minimise the included non-metallic content of the finished steel. Acceptable de-oxidation practices are given under the specific requirements in subsequent Sections of this Chapter.

The steel is to be cast in metal ingot moulds or by an approved continuous casting process. The size of the ingot or of the continuous cast billet or slab is to be proportional to the dimensions of the final product in order that the amount of mechanical work will be adequate to ensure a satisfactory steel structure in the finished product. Provision is also to be made for sufficient discard to be taken from the top and bottom of each ingot to ensure soundness in the portion used for further processing. Periodically and at the Surveyor's discretion sulphur prints or other suitable proving tests may be required to demonstrate that this has been fulfilled.

Testing and Inspection

103 The prescribed tests and inspection shall be carried out at the place of manufacture before despatch, but in the event of any material proving unsatisfactory during working or fabrication, such material shall be rejected not-withstanding any previous certificates, and the Surveyor may require further tests from other materials from the same batch.

All the test pieces are to be selected and stamped by the Surveyor or an authorised deputy and tested in his presence.

Surface Inspection and Dimensions

104 Surface inspection and verification of dimensions are the responsibility of the steelmaker, and acceptance by the Surveyors of material later found to be defective shall not absolve the steelmaker from this responsibility.

Identification of Materials

105 The steelmaker shall adopt a system for the identification of ingots, slabs and finished pieces which will enable the material to be traced to its original heat, and the Surveyors shall be given full facilities for so tracing the material when required.

Branding

106 Every finished item is to be clearly marked by the makers in at least one place with the Society's brand and the following particulars:—



- (i) Agreed identification mark for the grade of steel.
- (ii) Name or initials to identify the steelworks.
- (iii) Number and/or initials to identify the heat.
- (iv) Purchaser's identification mark if required by the purchaser.

Where a number of light materials are securely fastened together in bundles, the manufacturer may, subject to the agreement of the Surveyors, brand only the top piece of each bundle, or alternatively, a firmly fastened durable label containing the brand may be attached to each bundle.

Defacing of Rejected Material

107 In the event of any material, bearing the Society's brand, failing to comply with the test requirements, the brand is to be unmistakably defaced.

Mill Sheets

108 The Surveyor shall be supplied with at least two copies of the mill sheets or shipping statements of all accepted material which documents should be separate for each grade of steel. The documents shall contain, in addition to the description, dimensions, etc., of the material, the following particulars:—

- (i) Purchaser's identification marks.
- (ii) Identification of the heat.
- (iii) Identification of the steelworks.
- (iv) Identification of the grade of steel.
- (v) Ladle analysis (elements controlled by the specification only).
- (vi) Order or ship number for which intended.
- (vii) If the ship steel is of rimming quality, this should be stated.
- (viii) For higher tensile steel, the specified minimum yield stress and the specified tensile strength range are to be stated together with the actual carbon equivalent value (see P 302).

Maker's Certificate

signed by the Surveyor, the manufacturer is required to furnish him with a certificate stating the material has been made by an approved process and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor or his authorised deputy. The following form of certificate will be accepted if stamped or printed on each mill sheet with the name of the steelworks and initialled for the makers by an authorised official:—

Facilities for Inspection

110 The manufacturers shall afford the Surveyors all necessary facilities and access to all relevant parts of the works to enable them to verify that the approved process is adhered to, and for witnessing the selection and testing as required by the Rules, and for verifying the accuracy of the testing equipment.

Steel not Produced where Rolled

111 When steel is not produced at the Works at which it is rolled, a certificate shall be supplied to the Surveyor at the rolling mill stating the process by which it was manufactured, the name of the manufacturer who supplied it, the number of the heat from which it was made and the ladle analysis. The works at which the steel was produced must be approved by the Committee.

Tensile Test

112 The tensile tests shall be carried out by competent personnel in an approved machine of adequate capacity. The machine shall be maintained in a satisfactory and accurate condition and shall be re-calibrated at approximately annual intervals. This calibration is to be carried out by a nationally recognized authority or other organization of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations shall be kept available in the test house.

The tensile strength is defined as the maximum load divided by the original cross-sectional area of the tensile test piece.

Section 2

MILD STEEL FOR HULL STRUCTURES

NOTE. These requirements are primarily intended to apply to steel not exceeding 50 mm (2 in) in thickness. For greater thicknesses, certain variations in the requirements may be allowed or required in particular cases after consideration of the technical circumstances involved.

Freedom from Defects

201 (a) The minus tolerance in the thickness of plates and sections from those given on the approved plans is not to exceed:—

Nominal thi	ckness ''	t ''	То	lerance
	mm	in	mm	in
Not exceeding Over Not exceeding Over	15,0 15,0 45,0 45,0	$0.6 \\ 0.6 \\ 1.8 \\ 1.8$	0,4 (0,02t+0,1) 1,0	0·016 (0·02t+0·004) 0·04

The general standard as laid down by the Rules is to be maintained.

The thickness of plates is to be measured at positions which are approximately 40 mm (1.5 in) from an edge and 100 mm (4.0 in) from a corner.

- (b) The steel is to be reasonably free from segregations, surface flaws and non-metallic inclusions. The finished material is to be free from cracks and lamination. It shall also have a workmanlike finish, and must not have been hammer dressed.
- (c) Surface defects may be removed by grinding, provided that the thickness is in no place reduced to less than 93 per cent of the nominal thickness but in no case by more than 3 mm (0·125 in). The extent of such repairs shall be agreed in each case with the Surveyors, and the repairs shall be carried out under the Surveyors' supervision unless otherwise agreed.
- (d) Surface defects which cannot be dealt with as above may be repaired by chipping or grinding followed by welding, subject to the Surveyors' consent and under their supervision, provided:—
 - that after removal of the defect, and before welding, the thickness of the item is in no place reduced by more than 20 per cent,
 - (ii) that the welding is carried out by an approved procedure, by competent operators with approved electrodes, and that the welding is ground smooth to the correct nominal thickness,
 - (iii) that subsequent to the finish grinding, the piece may be required to be normalized or otherwise heat

treated at the Surveyors' discretion. Re-normalizing will always be required if the piece has been normalized before the repair.

Distinguishing Marks

202 The entire marking (see P 106) is to be surrounded by a clear mark in paint of the following distinctive colours:—

Grade A steel	***		1000	white
Grade B steel		***		green
Grade C steel	***	1992		blue
Grade D steel	111			red
Grade E steel	***	***		yellow

Where the name of the steelworks is embossed on finished sections, only the Society's brand and items (i), (iii) and (iv) of P 106 need be surrounded by paint in appropriate colour.

Standard Tensile Test Piece

203 This piece shall have a rectangular cross-section with thickness equal to that of the material from which it is cut and a width of 25 mm (1 in) with a length between gauge marks of 200 mm (8 in). The parallel length shall not be less than 230 mm (9 in). The ends of the test piece may be increased in width to suit the grips of the machine, the transition between the different widths being made with a gentle curve.

The test pieces are to be cut with their lengths transverse to the principal direction of rolling except in the case of sections and narrow flats, i.e., up to and including 610 mm (24 in) wide.

Alternative Tensile Test Pieces

204 Tensile test pieces of other dimensions or of cylindrical form may be used, provided that the elongations comply with 205, and provided that the cross-sectional area is not less than 161 mm² (0.25 in²).

Elongations in Tensile Test

205 (a) The required minimum elongations, E, are indicated in Table P 2.2. These elongations are based on test pieces having gauge lengths equal to 5,65 times the square root of the cross-sectional area, or 5 times the diameter.

(b) For test pieces having gauge lengths bearing other relationships to the cross-sectional area, the equivalent elongations shall be calculated from the following formula:—

$$E = \frac{n}{2} \left(\frac{Lo}{\sqrt{So}} \right)^{0.40}$$

where n = actual measured percentage elongation of test piece,

So = actual cross-sectional area of test piece,

Lo = actual gauge length of test piece,

E = equivalent percentage elongation for a test piece with a gauge length of $5,65\sqrt{SO}$.

NOTE. -- So and Lo may be in any consistent units.

(c) For the "standard" test piece (see 203) the minimum percentage elongations shall not be less than the following:—

Thickness	2	Mir	nimum Elongation
6 mm (0·25 in)			0,68E
30 mm (1.2 in) and o	over		0,95E

where E is the specified minimum percentage elongation for a test piece with a gauge length of $5,65\sqrt{s_0}$. The elongations for thicknesses between 6 mm and 30 mm (0.25 and 1.2 in) may be obtained from the above by linear interpolation.

Bend Tests

206 The bend test shall consist in bending a strip or bar of the material until the ends are parallel to each other, and at a distance apart not exceeding three times the thickness or diameter of the strip or bar.

The strips shall have a width at least equal to the thickness but not less than 25 mm (1 in) and a thickness not less than that of the material tested, retaining the original rolled surfaces. The sharp edges of the strip may be removed by filing or machining, to a radius not exceeding 0,1 of the thickness of the strip.

When the power of the available testing machine is insufficient to bend a test piece of the full thickness, this latter may be reduced by machining from one face or by turning down a round bar provided that the final thickness or diameter is not less than 25 mm (1 in). Strips shall be so bent that the original rolled surface is on the tension side.

The strips shall be cut with their lengths transverse to the principal direction of rolling except in the case of sections and narrow flats, i.e. up to and including 610 mm (24 in) wide. The bending may be performed by pressure or by blows.

The bend test will be considered successful if no cracks or laminations appear.

Impact Tests

V-notch type machined to the dimensions and tolerances given in Table P 2.1. Standard test pieces 10 mm square shall be used except where the thickness of the material

does not permit this size of test piece being prepared. In such cases the largest possible size of subsidiary test piece is to be prepared with the notch cut on the narrow face. Alternatively, for material of suitable thickness, the rolled surfaces may be retained so that the test piece width will be the full thickness of the material. The prescribed dimensions are to be carefully and systematically checked. The test pieces shall be cut with their longitudinal axes parallel to the final direction of rolling of the material. The notch shall be cut in a face of the test piece which was originally perpendicular to the rolled surface.

TABLE P 2.1

Dimensions and Tolerances for Charpy V-notch
Test Pieces

Dimensions	Nominal Dimension	Tolerance	
Length	55 mm	±0,60 mm	
Width Standard Subsidiary	10 mm 7,5 mm 5,0 mm	±0,11 mm ±0,11 mm ±0,05 mm	
Thickness	10 mm	±0,11 mm	
Angle of notch	45°	±2°	
Depth below notch	8 mm	±0,11 mm	
Root radius	0,25 mm	±0,025 mm	
Distance of notch from end of test piece	27,5 mm	±0,42 mm	
Angle between plane of symmetry of notch and longitudinal axis of test piece	90°	±2°	

The position of the notch shall not be nearer than 25 mm (1 in) to a flame-cut or sheared edge.

In the case of sections, the test pieces are to be cut from the thickest part.

The tests are to be carried out with the test pieces at a temperature carefully controlled to within $\pm 1~{\rm degC}$ of the required temperature, on a Charpy impact machine of approved type installed in an approved manner having a gap of 40 mm, a striking velocity between 4,5 and 6 m/second, and a striking energy of not less than 15 kg m. The angle of the striking edge of the pendulum is to be 30° with the

edge rounded to a radius not exceeding 2 mm. The machine is to be periodically checked and calibrated on the lines indicated in P 112.

Alternative Types of Test

208 Other alternative types of test may be substituted for the Charpy V-notch impact test provided that equivalent standards of notch ductility can be established to the satisfaction of the Society.

Number of Tensile Tests

209 For each batch presented, one tensile test shall be made from one piece rolled from each cast unless the weight of finished material is greater than 40 000 kg (40 tons) in which case one extra test shall be made from each 40 000 kg (40 tons) or fraction thereof. Additional tests are to be made for every variation of 5 mm (0·20 in) in the thicknesses of pieces from the same cast.

Number of Bend Tests

210 One bend test piece is to be prepared from material adjacent to each tensile test piece.

Number of Impact Tests (where required)

211 Unless otherwise specified for a particular grade of steel, at least one piece is to be selected for impact testing from the thickest batch from each cast, unless the weight of finished material rolled from the cast is greater than 40 000 kg (40 tons) in which case one extra test will be made from a different piece from each 40 000 kg (40 tons) or fraction thereof, provided that the same procedures have been used in manufacture.

When plates of different widths are included in batches of the same thickness the widest plate is to be preferred for testing.

From each piece so selected, three impact tests as described in 207 shall be carried out. The average values obtained from these tests shall comply with the requirements. If, however, the average obtained fails to comply by an amount not exceeding 15 per cent of the required value, three additional test pieces from the same sample may be tested, and the results added to those previously obtained to form a new average, which must comply with the requirements.

Definitions

212 The term "piece" is to be understood to mean the rolled product from a single slab or from a single ingot if this is rolled directly into plates, bars or sections. The term "item" means any single plate, bar or section as delivered. The term "test piece" where it occurs means the sample of material which is actually tested.

Additional Tests before Rejection

- 213 (a) When the tensile or bend tests on the first piece selected in accordance with 209 and 210 fail to meet the requirements, two further tests of the same kind may be made from the same piece. If both these additional tests are satisfactory the piece and the remaining pieces from the same cast may be accepted.
- (b) If the additional tests referred to in (a) are unsatisfactory the piece is to be rejected, but the remaining material from the same cast may be accepted provided that two of the remaining pieces selected in the same way are tested with satisfactory results.
- (c) If the impact tests, carried out in accordance with 211 on the first piece selected, fail to meet the requirements the piece is to be rejected, but the remaining material from the same cast may be accepted provided that two of the remaining pieces, selected in the same way, are tested in the same way with satisfactory results.
- (d) If any test piece fails because of faulty preparation or (in the case of a tensile test) because of fracturing outside the middle half of the gauge length, the defective test piece may at the Surveyor's discretion be discarded and replaced by an additional test piece from the same piece.
- (e) At the option of the steelmakers, rejected material may be re-submitted after heat treatment or re-heat treatment or may be re-submitted as another grade of steel, and may then be accepted provided that the required tests are satisfactory.

Position of Samples for Testing

214 Except where otherwise specially agreed, the samples taken from the rolled material for the preparation of test pieces are to be cut from the end of the piece corresponding to the top end of the ingot. When the axis of the ingot is transverse to the length of the piece, either end may be selected but the sample should preferably be taken near to the edge corresponding to the top of the ingot.

Heat Treatment

215 Unless otherwise specified, or required by the conditions of approval of the process, the material may be presented in the "as rolled" or heat treated condition at the maker's option, subject to full compliance with the remainder of these Rules, and provided that the material which is presented in the normalized or otherwise heat treated condition is to be tested separately from material presented in the "as rolled" condition, even when all such material is from the same cast.

The sample of material from which test pieces are cut must be heat treated together with and in the same way as

TABLE P 2.2

GRADE	A	В	C	D	E
1. METHOD OF MANU- FACTURE	As P 102	As P 102	Process to be specially approved	Process to be specially approved	Process to be specially approved
2. Deoxidation	Any method (For rimmed steel see Note 1)	Any method except rimmed steel.	Fully killed, fine grain practice (Aluminium treated)	Any method except rimmed steel	Fully killed, fine grain practice (Aluminium treated)
3. Austenitic Grain Size (McQuaid-Ehn method) ASTM scale (See P 217)	elevery bargers of the grant of the first later of the grant of the gr	a two sees oil cont apper publican oft any year soles file begoing it (a)	5 or finer To be determined on each charge (see Note 4)	po de la company	5 or finer To be determined on each charge
4. CHEMICAL COMPO- SITION (ladle analysis) Carbon Manganese Silicon Sulphur Phosphorus	See Note 2 See Note 2 0,05% max. 0,05% max.	0,21% max. 0,80% min. 0,05% max. 0,05% max.	0,23% max. 0,60% to 1,40% 5 0,15% to 0,30% 0,05% max. 0,05% max.	0,21% max. Note 0,60% to 1,40% 5 0,35% max. 0,05% max. 0,05% max.	0,18% max. 0,70% to 1,50% 0,10% to 0,35% 0,05% max. 0,05% max.
5. Tensile Test Tensile strength, kg/mm ² (ton/in ²) (See P 112)	41 to 50 (26 to 32)	41 to 50 (26 to 32)	41 to 50 (26 to 32)	41 to 50 (26 to 32)	41 to 50 (26 to 32)
Elongation on 5,65 \sqrt{SO} % minimum (See P 205)	22%	22%	22%	22%	22%
6. IMPACT TEST Test Temperature Minimum Energy Width of test piece			parties promined	kg m 0°C ft lb	-10°C kg m ft lb
10 mm 7,5 mm 5,0 mm (See Note 7)		at a sur — sig two to us gar of — subface or senter act or regul	- to stop the police	4,8 35 4,1 30 3,5 25	6,2 45 5,4 39 4,6 33 Every plate to be tested
7. Bend Test	As P 206	As P 206	As P 206	As P 206	As P 206
8. HEAT TREATMENT	See P 215	See P 215	Normalized over 33 mm (1.25 in) thick	See P 215	Normalized

NOTES-TABLE P 2.2

1. For Grade A, rimming steel may be accepted up to 12,5 mm (0.5 in) thick inclusive, provided that it is stated on the mill sheets to be rimming steel and is not excluded by the purchaser's order.

2. For Grade A in thicknesses over 12,5 mm (0.5 in) the manganese content shall not be less than 2,5 times the carbon content.

3. For Grade B, when the silicon content is 0,15 per cent or more (killed steel) the minimum manganese content may be reduced to 0,60 per cent.

4. For Grade C the determination of grain size may

be alternatively substituted by impact tests as required for Grade D.

- 5. For Grades B, C, D and E, the sum of carbon content plus $\frac{1}{6}$ of the manganese content shall not exceed 0.40 per cent.
- 6. In general, Grade C may be accepted as an alternative to Grade D.
- Where non-standard subsidiary impact test pieces are used, the minimum value may be obtained by interpolation.

the material presented. Test specimens may not be separately heat treated in any way.

Chemical Analysis

216 The chemical composition shall be determined by the makers in an adequately equipped and competently staffed laboratory on samples taken from each ladle of each cast. The maker's analysis will be accepted subject to occasional checks if required by the Surveyors.

Austenitic Grain Size

217 The austenitic grain size where required is to be determined by the McQuaid-Ehn method from samples representative of each ladle of each cast. The grain size numbers indicated refer to the ASTM scale described in ASTM E112-63T, or any later ASTM specification which may supersede it.

Applications

218 For information regarding requirements for the application of different grades of steel, reference should be made to the following paragraphs:—

D 410, D 411, D 422, D 512, D 513, D 4008, D 4009, Sections D 70, D 71 and D 72.

Section 3

HIGHER TENSILE STEEL FOR HULL STRUCTURES

The following paragraphs do not constitute a complete specification for higher tensile steel for hull construction but are intended for the guidance of Steelmakers and Shipbuilders.

General

301 The requirements of P1 and P2 are to be complied with so far as they are applicable and as amended in the following paragraphs.

Approval of Steel

302 Full details of the method of manufacture including chemical composition, heat treatment and mechanical properties are to be submitted for approval. If considered necessary, tests are to be made on samples of steel manufactured in accordance with the proposed specification.

The steel should be capable of being fabricated and welded under shippard conditions. When the carbon equivalent calculated from the ladle analysis and using the formula given below, is in excess of 0,45% approved low hydrogen higher tensile electrodes and preheating are to be used. When the carbon equivalent is not more than 0,45% approved low hydrogen higher tensile electrodes are to be used but preheating will not generally be required except under conditions of high restraint or low ambient temperature. When the carbon equivalent is not more than 0,41% any type of approved higher tensile electrodes may be used and preheating will not generally be required except as above.

Carbon equivalent C.E. =

$$\mathtt{C} + \frac{\mathtt{Mn}}{6} + \frac{\mathtt{Cr} + \mathtt{Mo} + \mathtt{V}}{5} + \frac{\mathtt{Ni} + \mathtt{Cu}}{15}$$

This formula is only applicable to steels which are basically of the carbon-manganese type containing minor quantities of grain refining elements, for example, niobium, vanadium or aluminium, and the proposed use of low alloy steels will be subject to special consideration.

Number of Tests

303 The number of tests required will depend on the proposed chemical composition and heat treatment of the steel and will be agreed with the manufacturer at the time of approval or after a trial period of production.

The number of tests required, however, will not be less than:—

For Grades AH and DH steel one tensile test, one bend test and one set of three Charpy V-notch tests are to be made from one piece rolled from each cast unless the weight of finished material is greater than 40 000 kg (40 tons) in which case one extra set of tests is to be made from each 40 000 kg (40 tons) or fraction thereof. Additional tests are to be made for every variation of 5 mm (0·20 in) in the thicknesses of pieces from the same cast (see also footnote to 304 (f)).

For Grade EH steel one tensile test and one bend test is to be made as above and in addition one set of three Charpy V-notch tests are to be made from each piece (see P 212) provided all items cut from each piece are heat treated at the same time.

Mechanical Properties

304 (a) All test pieces are to be prepared in accordance with the requirements for mild steel as given in P 2.

(b) The tensile strength is to be within the limits given in the approved specification. The specified range between maximum and minimum is not to exceed 12,6 kg/mm² (8 ton/in²).

- (c) The yield stress is to be not less than the value given in the approved specification and, in any particular test is not to exceed 80% of the actual tensile strength. (See also 305).
- (d) The percentage elongation on a gauge length of $5,65\sqrt{s_0}$ is to be not less than the value given in the approved specification.
- (e) Bend Tests. The test pieces are to be bent cold without fracture. The diameter of the former and the angle of bend are to comply with the approved specification.
- (f) The Charpy V-notch impact values are to be determined in accordance with P 207 and P 211. The percentage crystallinity, based on the original area is to be recorded for information.

GRADE	TEST	MINIMUM ENERGY		
	TEMP.	kg m	ft lb	
AH (For Grade A application)	0°C	2,765 (see Note)	20 (see Note)	
DH (For Grade D application)	0°C	$4,84 \frac{1}{\sqrt{k}}$	$35 \frac{1}{\sqrt{k}}$	
EH (For Grade E application)	−10°C	$6,22 \frac{1}{\sqrt{k}}$	$45 \frac{1}{\sqrt{k}}$	

where
$$K = \frac{70,9}{Y + U}$$
 $\left(K = \frac{45}{Y + U} \text{ British}\right)$

- and Y = specified minimum upper yield stress or 0,5% proof stress in kg/mm² (ton/in²) or 0,7U whichever is the less.
 - U = specified minimum tensile strength plus one half of the specified range, in kg/mm² (ton/ in²).

Note. The necessity for impact testing of Grade AH plates will depend on the particular method of manufacture and will be decided when the specification is submitted for approval.

Determination of Yield Stress

305 When a beam type testing machine is being used the yield stress is to be calculated from the load immediately prior to a distinct drop of the beam.

When an indicator type of testing machine is being used the yield stress is to be calculated from the load immediately prior to a fall back in the movement of the pointer, or the load at a marked hesitation of the pointer.

Where no distinct yield is observed either the 0,2% proof stress or the 0,5% proof stress under load is to be determined.

The 0,2% proof stress is to be calculated from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and distant from it by an amount representing 0,2% of the extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2% proof stress can be calculated.

The 0,5% proof stress under load is to be calculated from the load corresponding to a total extension of 0,5% of the original gauge length. This extension is to be measured either by the use of a suitable extensometer or by dividers.

In all cases the rate of increase of stress in the upper half of the elastic range and until the yield or proof load has been reached is not to be greater than 1 kg/mm²/second (0·6 ton/in²/second). After reaching the yield or proof load the rate of straining may be increased to a maximum of 40% of the original gauge length per minute for the determination of the tensile strength.

Surface Inspection

306 Attention is drawn to P 104 and it is recommended that both surfaces of all plates be carefully inspected at the steelworks and the edges examined for laminations or other defects.

Freedom from Defects

307 If surface defects are repaired by welding (see P 201 (c)) the procedure shall be appropriate to the steel and a suitable heat treatment will be required.

Marking

308 Distinguishing marks are to be as required by P 106 and P 202 but the grade mark is to be followed by a letter "H" (as in 304 (f)). A large letter "H" is also to be painted near the brand marking in the appropriate colour given in P 202.

Section 4

STEEL RIVET BARS AND MANUFACTURED RIVETS

Testing of Material

401 All material from which rivets are manufactured is to be tested.

Rivets are not to be manufactured from steel in which the sulphur segregates and other non-metallic substances are concentrated in the core. To ensure this, a sulphur print is to be taken from the material of each cast, and where the weight of bars as rolled from one cast exceeds 10 000 kg (10 tons), additional sulphur prints may be taken.

Number of Tests

402 One tensile test piece is to be taken from each cast used for rivet bars; but where the weight of bars as rolled from one cast exceeds 10 000 kg (10 tons) an additional tensile test is to be made from each further 10 000 kg (10 tons) or portion thereof.

403 One dump test is to be made for each tensile test.

Tensile Test Pieces

404 Rivet bars may be tested in full section or may be machined to a convenient size provided the cross-sectional area is not less than $161~\mathrm{mm^2}~(0.25~\mathrm{in^2})$. Where a gauge length other than $5.65\sqrt{\mathrm{So}}$ is used the equivalent elongation is to be calculated using the formula given in P 205.

Tensile Test

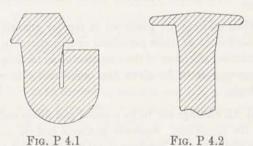
405 The tensile strength of steel rivet bars is to be within the limits of 41 and 50 kg/mm² (26 and 32 ton/in²) and the elongation on a gauge length of $5,65\sqrt{s_0}$ is to be not less than 26 per cent.

Dump Test

406 Short lengths, equal to twice their diameter, cut from the rivet bars shall, when cold, withstand without fracture being compressed to half their length.

Manufactured Rivets

407 Rivets selected by the Surveyor from the bulk are to withstand the tests described in 408 to 410.



408 The rivet shanks are to be bent cold, and hammered until the two parts of the shank touch in the manner shown in Fig. P 4.1, without fracture on the outside of the bend.

409 The rivet heads are to be flattened, while hot, in the manner shown in Fig. P 4.2, without cracking at the edges. The heads are to be flattened until their diameter is 2.5 times the diameter of the shank.

410 In the case of steel rivets, samples are to be selected by the Surveyor for examination by means of

sulphur prints, to ensure that the material is free from marked central segregation.

Section 5

STEEL CASTINGS

Scope

501 Cast steel sternframes, rudder frames, rudder stocks, propeller shaft brackets and other steel castings intended for use in hull construction are to be manufactured and tested in accordance with the requirements of this section.

Where it is proposed to use low alloy steel castings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. These castings are to be tested and accepted on the basis of the approved specification and such other tests as may be considered necessary.

Manufacture

502 All castings are to be made at foundries approved by the Committee.

Steel is to be manufactured in accordance with P 102.

All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be completed before the final heat treatment of the casting and preheating is to be applied where necessary. The affected parts are to be ground smooth.

Chemical Composition

503 Castings are to be made in carbon or carbon manganese steel. The chemical composition of ladle samples is to comply with the following:—

Carbon ... 0,23% max. Silicon... 0,60% max.

Manganese ... 1,60% max. but not less than 3 times the actual carbon content.

Sulphur ... 0,050% max. Phosphorus ... 0,050% max.

Residual elements, nickel, chromium, molybdenum, copper:—total not to exceed 0,8%.

Heat Treatment

504 Steel castings are to be heat treated by any of the following methods:—

(1) Full annealing by heating to a temperature within the range 850°C to 950°C followed by cooling slowly in the furnace in a uniform manner.

- (2) Normalizing by heating to a temperature within the range 850°C to 950°C followed by cooling in air and, where appropriate, subsequently tempering at a temperature of not less than 620°C.
- (3) A combination of both of these treatments, e.g., annealing or homogenizing at a relatively higher temperature as a preliminary refining treatment to subsequent normalizing and tempering as in (2).

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for temperature control and are fitted with pyrometers which measure the temperature of the furnace charge. The furnace dimensions must permit the whole item being uniformly heated to the necessary temperature.

Test Material

505 (a) Test material for the preparation of at least one tensile and one bend test piece is to be cast attached to each casting at positions agreed between the manufacturer and Surveyor. When larger castings are made from more than one cast of steel, or are of complex design, the number of tests is to be agreed with the Surveyor.

The test material is not to be cut from the castings until heat treatment has been completed nor until the test material has been stamped by the Surveyor.

- (b) The tensile test piece is to be machined to a diameter of 14 mm (0.564 in) with a gauge length of 70 mm (2.80 in). Alternatively, at the request of the manufacturer, test pieces with other gauge lengths or larger diameters may be used.
- (c) Bend test pieces are to be machined to either a rectangular section 25 mm (1 in) wide by 20 mm (0.75 in) thick or a round section 25 mm (1 in) diameter. The sharp edges of rectangular section test pieces may be removed by suitable mechanical means to a radius not exceeding 1,5 mm (0.0625 in).

Mechanical Properties

- 506 (a) All tests are to be carried out in the presence of the Surveyor.
- (b) The tensile strength is to be between the limits of 41 and 55 kg/mm² (26·0 and 35·0 ton/in²).

Elongation values are to be reported on a gauge length equal to $5,65\sqrt{S_0}$, where SO is the cross-sectional area of the test piece. The elongation is to be not less than 20% and where the actual gauge length used is other than $5,65\sqrt{S_0}$ the equivalent elongation is to be calculated using the formula or factors given in P 205 or Q 202.

The bend test piece is to withstand being bent through an angle of 120° round a former having a diameter not greater than 60 mm ($2 \cdot 25$ in).

- (c) If for any reason after testing as above, a casting is given a further full annealing or normalizing heat treatment, e.g., after weld repairs, then the original tests are to be disregarded and further complete mechanical tests are to be made.
- (d) Where either the tensile test or the bend test, or both, fail to meet the specified requirements, and the Surveyor considers the fractured test piece or test pieces, or the results obtained therefrom, do not fairly represent the quality of the casting, two further test pieces of the same type are to be taken for each original test that failed. In such cases the quality of the casting is to be judged by the result of the re-tests and not by the original test or tests which failed.

When one or both of the retests fail then the casting is to be rejected.

(e) At the option of the manufacturer, when tests on a casting fail to meet the specified requirements, the casting may be re-heat treated and re-submitted for test provided it is not heated above the upper critical temperature more than three times, i.e., original and two re-treatments.

Inspection

507 (a) The manufacturer is to make any tests necessary to prove the casting technique for prototype castings.

When castings are produced in regular quantities the manufacturer is to make periodical examinations to verify the continued efficiency of the manufacturing technique and the Surveyor is to be given the opportunity to witness these tests.

- (b) All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. Before examination the surfaces must not be hammered, peened or treated in any way which may obscure defects.
- (c) All important castings are to be examined by magnetic particle methods in at least all areas containing changes of section and where surplus metal has been removed by flame cutting, scarfing or arc-air gouging. The techniques employed are to be in accordance with recognised good practice, including any necessary surface preparation and are to be carried out by competent personnel using reliable and efficiently maintained equipment. The

term "magnetic particle examination" is intended to imply inspection for surface flaws using suitable magnetic methods but when this is not practicable a suitable dye penetrant method may be used instead.

- (d) In all cases, in order to determine the soundness of the castings, supplementary examinations by radiography, ultrasonic, or other approved methods of non-destructive testing may be requested. When such examination is to be carried out it should be at positions, mutually agreed by the Surveyor and manufacturer, where experience shows that cavities, contraction cracks, or other defects are most likely to occur.
- (e) The Surveyor is to examine each large casting before final acceptance at the foundry.

Repair of Defects

- 508 (a) When defects are found in a casting these are to be removed by grinding or by chipping and grinding. Flame scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting depressions are subsequently ground smooth. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can, at the Surveyor's discretion, be accepted provided these are blended by grinding.
- (b) Proposals to repair a defective casting by welding are to be submitted to the Surveyor before work is commenced. The Surveyor is to satisfy himself that the number and size of the defects are such that the casting can be efficiently repaired.

When it has been agreed that the casting can be repaired it is to be proved by suitable methods of inspection that the defects have been completely removed and the defective area is to be prepared in a form suitable for welding. All castings in alloy steels and, if necessitated by the shape, castings in carbon or carbon manganese steels are to be given a preliminary refining heat treatment prior to carrying out weld repairs. Such castings are also to be pre-heated to a suitable temperature. An electric arc welding process is to be used and the weld deposit is to have properties similar to and in no way inferior to the parent metal. Welding of the affected parts is to be undertaken by a procedure the essential elements of which have been tested previously by the manufacturers and approved by the Surveyor. The welding is to be done under cover in positions free from draughts and adverse weather conditions by competent welders with adequate supervision.

After welding the castings are to be suitably heat treated either by annealing, normalizing and tempering or stress relieving at a temperature of not less than 600°C. The type of heat treatment employed will be dependent on the size, position and nature of the defects. On completion of heat treatment, the weld repairs and adjacent metal are to be ground smooth and proved by a suitable method of magnetic particle inspection. Subject to the approval of the Surveyor, a local stress relieving heat treatment may be carried out where the area involved is small and machining of the casting has reached an advanced stage.

Identification

- 509 Before any casting is finally accepted it is to be clearly marked by the manufacturer in at least one place with the following particulars:—
 - (i) "L.R." or "Lloyd's" and the abbreviated name of the Society's local office.
 - (ii) Identification mark which will enable the full history of the casting to be traced.
 - (iii) Date of final inspection.
 - (iv) Personal stamp of Surveyor responsible for final inspection.

Documentation

510 The manufacturer is to supply the Surveyor with a written statement giving the steelmaking process, cast number, cast analysis, mechanical test results and general details of heat treatment together with full particulars of the purchaser, order number and description.

When repairs have been made by welding the manufacturer may be requested to provide the Surveyor with a statement and/or sketch detailing the extent and location of the repairs together with details of the heat treatment carried out at all stages.

Section 6

STEEL FORGINGS

Scope

601 Forgings for sternframes, rudder frames, rudder stocks, propeller shaft brackets and other steel forgings intended for use in hull construction are to be manufactured and tested in accordance with the requirements of this section. These requirements are also applicable to rolled slabs or billets used as a substitute for forgings.

Where it is proposed to use low alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. These forgings are to be tested and accepted on the basis of the approved specification and such other tests as may be considered necessary.

Manufacture

602 (a) The steel is to be manufactured in accordance with P 102.

When forgings are made from ingots, or from blooms forged from ingots, the ingots are to be cast in metal moulds with the larger cross-section uppermost and with efficient feeder heads. The forgings are to be gradually and uniformly hot worked and are to be brought as nearly as possible to the finished shape and size. Where practicable they are to be worked so as to cause metal flow in the most favourable direction having regard to the mode of stressing in service. Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

Unless otherwise approved the maximum sectional area of any part of a forging (as forged) is not to exceed:—

- ¹₃A where the length of any section is greater than its diameter,
- ²₃A where the length of any section is less than its diameter (e.g., a collar).
- A is the average sectional area of the ingot or of the ingot after upsetting if such an operation is involved.
- (b) When forgings are made from rolled products the maximum sectional area of a forging (as forged) is not to exceed:—
 - (i) when made from products rolled from ingots cast large end uppermost with efficient feeder heads,
 A where the length of any section is greater than its diameter,
 - or ½A where the length of any section is less than its diameter (e.g., a collar),
- or (ii) when made from products rolled from other types of ingots,

¹/₆A where the length of any section is greater than its diameter,

or ¹/₃A where the length of any section is less than its diameter (e.g., a collar),

A is the average cross-sectional area of the original ingot.

(c) The shaping of forgings or rolled products by flame cutting is to be undertaken in accordance with a procedure approved by the Surveyor. Pre-heating is to be employed when necessitated by the thickness and on completion of shaping the forgings or rolled products may require to be heat treated in accordance with 604 (b).

Chemical Composition

603 (a) Forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component are to be made in carbon or carbon-manganese steel. The chemical composition of ladle samples is to comply with the following:—

Carbon ... 0,23% max.

Silicon... 0,15-0,50%

Manganese ... 0,30-1,60% but not less than 3 times the actual carbon content for components which are not given a post-weld heat treatment.

Sulphur ... 0,050% max.

Phosphorus ... 0,050% max.

Residual elements, nickel, chromium, molybdenum, copper:—total not to exceed 0,8%.

(b) For forgings not intended for welding the chemical composition of ladle samples is to comply with the following:—

Carbon ... 0,30% max.

Silicon... 0,15-0,50%

Manganese ... 0,30-1,60%

Sulphur ... 0,050% max.

Phosphorus ... 0,050% max.

Residual elements, nickel, chromium, molybdenum, copper:—total not to exceed 0,8%.

(c) Rolled products and forgings made from rolled products may have a silicon content of less than 0,15% i.e. semi-killed steel, provided that the cross-sectional area does not exceed 195 cm² (30 in²).

Heat Treatment

- 604 (a) All forgings and rolled products intended as a substitute for forgings are to be heat treated by any of the following methods:—
- (1) Full annealing by heating to a temperature within the range 850°C to 950°C followed by cooling slowly in the furnace in a uniform manner.

- or (2) Normalizing by heating to a temperature within the range 850°C to 950°C followed by cooling in air and subsequently tempering at a temperature of not less than 580°C if the diameter of the body of the forging is equal to or greater than 900 mm (35 in). Smaller diameter forgings may also be tempered after the normalizing heat treatment at the option of the forgemaster.
- (b) If flame cutting or shaping is carried out subsequent to the above heat treatment, a further normalizing or a stress relieving heat treatment may be required, depending on the extent of flame cutting and whether sufficient material is subsequently to be machined from the flame cut surfaces.

When a stress relieving heat treatment is required, this is to be carried out in the temperature range of 600°C to 650°C.

- (c) Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for temperature control and are fitted with pyrometers which measure the temperature of the furnace charge. The furnace dimensions must permit the whole item being uniformly heated to the necessary temperature.
- (d) Rolled products intended for forging stock and subsequent hot working do not require to be supplied in the heat treated condition.

Test Material

- 605 (a) Test material is to be provided integral with the forging and with a cross-sectional area of not less than that of the main part of the forging. At least one tensile and one bend test are to be taken from each forging, except where both the weight and length are in excess of 4000 kg (4 tons) and 3 m (10 ft) respectively, when tensile and bend tests are to be taken from each end. These limits refer to the "as forged" weight and length but excluding the test material.
- (b) When a forging is subsequently divided into a number of items all of which are heat treated together in the same furnace then for test purposes this may be considered as one forging and the test material required is to be related to the total length and weight of the original forging.

Where a number of separate forgings are made from one cast of steel and are heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

- (c) For rolled products at least one tensile and one bend test piece are to be taken from each piece (see P 212) except where these are intended for forging stock and will subsequently be hot worked.
- (d) Tensile and bend test pieces are to be cut longitudinally or parallel to the direction of principal grain flow. Where test pieces cannot reasonably be provided in the longitudinal direction they may be cut in a transverse direction. The test material is not to be cut from the forgings until heat treatment has been completed nor until the test material has been stamped by the Surveyor.
- (e) The tensile test piece is to be machined to a diameter of 14 mm (0.564 in) with a gauge length of 70 mm (2.80 in). Alternatively, at the request of the manufacturer, test pieces with other gauge lengths or larger diameters may be used.

Bend tests are to be machined to a rectangular section 25 mm (1 in) wide and 20 mm (0.75 in) thick. The sharp edges of the test pieces may be removed by suitable mechanical means to a radius not exceeding 1,5 mm (0.0625 in).

Mechanical Properties

- 606 (a) All tests are to be carried out in the presence of the Surveyor.
- (b) The tensile strength is to be between the limits of 44 and 54 kg/mm² ($27 \cdot 9$ and $34 \cdot 3$ ton/in²).

Elongation values are to be reported on a gauge length equal to $5,65\sqrt{S_O}$, where SO is the cross-sectional area of the test piece. The elongation is to be not less than 22% for tests in the longitudinal direction and not less than 18% for tests in the transverse direction. Where the actual gauge length used is other than $5,65\sqrt{S_O}$ the equivalent elongation is to be calculated using the formula or factors given in P 205 or Q 202.

Bend test pieces which are cut in a longitudinal direction are to withstand being bent without fracture through an angle of 180° round a former having a diameter not greater than 12.5 mm (0·5 in). For test pieces cut in a transverse direction the diameter of the former is to be not greater than 25 mm (1 in).

(c) Where either the tensile test or the bend test, or both, fail, and the Surveyor considers the fractured test piece or test pieces, or the results obtained therefrom, do not fairly represent the quality of the forging then the procedure given in P 506 (d) or (e) may be adopted.

Inspection

607 The Surveyor is to examine each forging before final acceptance at the forge.

Repair of Defects

- 608 (a) When defects are found in a forging these are to be removed by grinding or by chipping and grinding. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can be accepted at the Surveyor's discretion provided they are blended by grinding.
- (b) Repair by welding is not generally permitted but special consideration will be given to such repairs when they are of a minor nature and in areas of low working stresses. Proposals are to be submitted to the Surveyor before work is commenced and the Surveyor is to satisfy himself that the number and size of the defects are such that the forgings can be efficiently repaired.
- (c) When it has been agreed that the forging can be repaired it is to be proved by suitable methods of inspection that the defects have been completely removed and the defective area is to be prepared in a form suitable for welding. An electric arc welding process is to be used and the weld deposit is to have properties similar to and in no way inferior to the parent metal. Welding of the affected parts is to be undertaken by a procedure the essential elements of which have been tested previously by the manufacturer and approved by the Surveyor. The welding is to be done under cover in positions free from draughts and adverse weather conditions by competent welders with adequate supervision.

After welding the forgings are to be suitably heat treated either by annealing, normalizing and tempering or stress relieving at a temperature of not less than 600°C. The type of heat treatment employed will be dependent on the size, position and nature of the defects. On completion of heat treatment, the weld repairs and adjacent metal are to be ground smooth and proved by a suitable method of magnetic particle inspection.

Identification

609 Forgings are to be identified in the same manner as for steel castings (see P 509).

Documentation

610 The manufacturer is to supply the information required as for steel castings (see P 510).

When repairs have been made by welding the manufacturer is to provide a written statement and/or sketch detailing the extent and location of the repairs together with details of the heat treatment carried out at all stages.

Section 7

STEEL ANCHORS

Process of Manufacture

701 Forged steel anchor heads and shanks are to be manufactured and tested in accordance with the relevant requirements of P 6 except that heat treatment need only be carried out when the weight of the forging exceeds 3000 kg (3 tons).

Cast steel anchor heads and shanks are to be manufactured and tested in accordance with the relevant requirements of P 5 except that where more than one anchor casting is made from the same cast, only one tensile and one bend test piece need be taken provided all the castings are heat treated in the same batch and that the weight of the cast is 3000 kg (3 tons) or less. Additional tests are to be taken when the cast is in excess of this weight.

702 Each important part of an anchor is to be plainly marked by the maker with the words "forged ingot steel" or "heat treated cast steel" as the case may be (or simply "forged steel" or "cast steel").

703 Steel anchor shackles are to be made of forged steel or cast steel as specified in 701, but need not be submitted to the test requirements of P 5 and P 6.

Proof Tests of Anchors

704 Anchors weighing more than 76 kg (168 lb) inclusive of stock, are to be tested at a proving establishment recognized by the Committee (see D 3420). When the (United Kingdom) Anchor and Chain Cable Act applies* the anchors are to be tested at a certified testing establishment.

*Note. The Anchor and Chain Cable Act, 1967, applies to anchors used on ships registered in the United Kingdom.

- 705 The test load is to be given in Table P 7.1. The weight to be used in the Table is:—
- (a) for stockless anchors—the total weight of the anchor,
- (b) for stocked anchors—the weight of the anchor excluding the stock,
- (c) for high holding power anchors (see D 3412)—a nominal weight equal to 1,33 times the actual total weight of the anchor.

TABLE P 7.1—PROOF TESTS FOR ANCHORS

Weight of Anchor (See P 705)	PROOF TEST LOAD										
kg	kg										
50	2370	500	11 800	2000	35 600	4500	63 400	7000	81 300	15 000	117 700
55	2570	550	12 700	2100	36 900	4600	64 300	7200	82 600	15 500	119 500
60	2760	600	13 500	2200	38 300	4700	65 100	7400	83 800	16 000	120 900
65	2950	650	14 300	2300	39 600	4800	65 800	7600	85 000	16 500	122 200
70	3130	700	15 200	2400	40 900	4900	66 600	7800	86 100	17 000	123 500
75	3300	750	16 100	2500	42 200	5000	67 400	8000	87 000	17 500	124 700
80	3460	800	16 900	2600	43 500	5100	68 200	8200	88 100	18 000	125 900
90	3700	850	17 800	2700	44 700	5200	69 000	8400	89 200	18 500	127 000
100	3990	900	18 600	2800	45 900	5300	69 800	8600	90 300	19 000	128 000
120	4520	950	19 500	2900	47 100	5400	70 500	8800	91 400	19 500	129 000
140	5000	1000	20 300	3000	48 300	5500	71 300	9000	92 400	20 000	130 000
160	5430	1050	21 200	3100	49 400	5600	72 000	9200	93 400	21 000	131 000
180	5850	1100	22 000	3200	50 500	5700	72 700	9400	94 400	22 000	132 000
200	6250	1150	22 800	3300	51 600	5800	73 500	9600	95 300	23 000	133 000
225	6810	1200	23 600	3400	52 700	5900	74 200	9800	96 200	24 000	134 000
250	7180	1250	24 400	3500	53 800	6000	74 900	10 000	97 100	25 000	135 000
275	7640	1300	25 200	3600	54 800	6100	75 500	10 500	99 300	26 000	136 000
300	8110	1350	26 000	3700	55 800	6200	76 200	11 000	101 500	27 000	137 000
325	8580	1400	26 700	3800	56 800	6300	76 900	11 500	103 600	28 000	138 000
350	9050	1450	27 500	3900	57 800	6400	77 500	12 000	105 700	29 000	139 000
375	9520	1500	28 300	4000	58 800	6500	78 200	12 500	107 800	30 000	140 000
400	9980	1600	29 800	4100	59 800	6600	78 800	13 000	109 900	31 000	141 000
425	10 500	1700	31 300	4200	60 700	6700	79 400	13 500	111 900	THE STATE OF	
450	10 900	1800	32 700	4300	61 600	6800	80 100	14 000	113 900		THE .
475	11 400	1900	34 200	4400	62 500	6900	80 700	14 500	115 900	listing 1	FIFT

or in British units:-

TABLE P 7.1—PROOF TESTS FOR ANCHORS

WEIGHT OF ANCHOR (See P 705)	PROOF TEST LOAD										
Cwt	Tons										
1	2.37	19	19.44	.58	46.9	108	70.1	158	85.8	300	117.0
11	2.85	20	20.28	60	48.1	110	70.8	160	86.3	310	118-0
$1\frac{1}{2}$	3.27	21	21.12	62	49.2	112	71.5	162	86.9	320	120.0
134	3.65	22	21.92	64	50.2	114	72.3	164	87.4	330	121.0
2	3.98	23	22.74	66	51 · 3	116	73.0	166	88.0	340	122.0
$2\frac{1}{2}$	4.63	24	23.48	68	52-4	118	73.7	168	88.5	350	123.0
3	5.18	25	24.33	70	53.4	120	74.3	170	89.0	360	124 - 0
31/2	5.70	26	25.12	72	54.5	122	75.0	172	89 · 6	370	125 · 0
4	6.20	27	25.87	74	55.5	124	75.7	174	90.1	380	126.0
41/2	6.68	28	26.52	76	56.5	126	76.3	176	90.6	390	127 - (
5	7.14	29	27.46	78	57-5	128	77.0	178	91.2	400	128 · 0
51/2	7.61	30	28.25	80	58.5	130	77.6	180	91.8	420	129.0
6	8.07	32	29.75	82	59 · 4	132	78 - 2	185	92.9	440	130 · (
7	9.03	34	31 · 13	84	60.3	134	78.9	190	94.0	460	131 - 8
8	9.95	36	32.53	86	61 · 2	136	79.5	195	95 · 1	480	132 - 8
9	10.85	38	34.10	88	62 · 1	138	80 · 1	200	96.5	500	133 - 5
10	11.76	40	35 · 45	90	63.0	140	80.7	210	99.0	520	134 - 5
11	12.65	42	36.79	92	63.9	142	81 · 4	220	101.0	540	135 - 5
12	13.44	44	38 · 11	94	64 · 6	144	82.0	230	103.0	560	136 -
13	14.25	46	39 · 27	96	65 · 4	146	82.6	240	105.0	580	137 -
14	15.16	48	40.75	98	66 - 2	148	83.2	250	107.0	600	138 -
15	16.04	50	42.1	100	67.0	150	83.8	260	109.0	620	139 -
16	16.83	52	43.3	102	. 67 - 8	152	84.3	270	111.0	T I I I	1 - 0
17	17.72	54	44.5	104	68-6	154	84.8	280	113.0		1
18	18.55	56	45.7	106	69.3	156	85.3	290	115.0	TO THE	

Section 8

CHAIN CABLES AND STEERING CHAINS

Note. For list of approved manufacturers see Appendix following Chapter Q.

Scope

801 Provision is made for the testing of bar material intended for the manufacture of welded chain, material tests for drop forged and cast links and the testing of completed chain, attachment links and shackles. Chain cables or steering gear chains may be of any one of the grades shown in Table P 8.1.

Method of Manufacture

802 The methods of manufacture of Grades 1(a) and 1(b) do not require to be approved but rimming steel should not be used.

803 The steel used for the manufacture of Grades U 1, U 2 and U 3 chain cable is to be made in accordance with P 102. Rimming steel is not acceptable.

The links may be made by the flash-butt or other approved welding process or they may be steel castings or drop forgings. The method of manufacture and the chemical composition are to be approved and the requisite preliminary tests carried out. Approval tests for higher grades cover lower grades (up to the same diameter) provided the method of manufacture and heat treatment are generally the same.

Chemical Composition

804 The chemical composition is to comply with the manufacturer's approved specification and is to be determined in accordance with P 216.

Heat Treatment

805 (a) Bar material intended for the manufacture of chain may be supplied in the "as rolled" or heat treated condition in accordance with the requirements of the chain maker.

(b) Heat Treatment of Completed Chain. Grade U 1 chain cable may either be supplied in the "as welded" condition or may be normalized. If supplied in the "as welded" condition additional breaking tests will be required as detailed in Table P 8.2.

Grade U 2(a) cable is to be normalized. Grade U 2(b) cast steel cable is to be normalized, or may, at option of the manufacturer, be hardened by quenching and tempered.

Grade U 3 cable is to be normalized, normalized and tempered, or hardened by quenching and tempered.

In all cases heat treatment is to be carried out prior to the proof loading and breaking tests of the completed chains and links.

806 For certain types of drop forged cable the requirements of 805, and the procedure for material tests, will be specially considered.

Test Material and Test Pieces

807 (a) For Grades U 1 and U 2(a) the bar material may be tested either in the "as rolled" condition or after heat treatment in full size and in a manner simulating the heat treatment applied to the finished cable. For Grade U 3(a) the test material is to be heat treated in full size and in a manner simulating the treatment applied to the finished chain.

Test material representative of cast or drop forged links is to be heat treated along with and in the same manner as the completed cable (see also 806).

(b) For all grades of chain cable one set of material tests as required by Table P 8.1 is to be taken. For bar material intended for the manufacture of fire welded or flash-butt welded cable and for drop-forgings, this set of tests is to be taken from the largest diameter bar (forging) in each batch of 40 tonnes (tons) or fraction thereof from the same cast. For cast steel cable, the sets of tests are to be taken from separately cast test blocks representative of each of the casts used to manufacture the cable.

From completed chain, 3-link samples are to be selected by the Surveyor for the breaking tests specified in 810(b). In addition, for Grade U 3, extra links are required for mechanical tests specified in 810(c).

(c) Tensile test pieces may be either the full section "as rolled" or of the round proportional type provided the cross-sectional area is not less than 161 mm² (0·25 in²), and the machining is in accordance with a recognized National Standard. For machined test pieces the diameter of the reduced portion and the position of the test piece relative to the bar cross-section are to be selected so that the test piece is representative of the average properties of the bar.

For cast or drop forged links test pieces of the machined type are to be used.

The gauge length is generally to be five times the diameter of the test portion. For other gauge lengths the equivalent elongations are to be determined in accordance with P 205(b). For Grade U 3(a) cable the minimum reduction of area = 40 per cent, for Grade U 3(b)=35 per cent.

Bend test pieces may be either the full section as rolled, or may be machined to 25 mm (1 in) diameter, or rectangular cross section 25×19 mm (1×0.75 in).

Impact test pieces are to be of the Charpy V-notch type in accordance with P 207. They are to be cut as shown in Fig. P 8.1:—

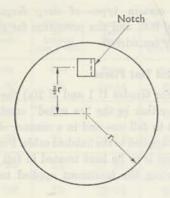


Fig. P 8.1

(d) Additional tests before rejection may be taken in accordance with P 213.

Mechanical Properties

808 In all cases the results of tensile bend and impact tests are to comply with Table P 8.1.

Inspection and Testing of Completed Chain

809 All chain cable and steering chains are to be tested at a proving establishment recognized by the Committee (see D 3420). When the (United Kingdom) Anchor and Chain Cable Act* applies the cables are to be tested at a certified testing establishment.

*Note. The Anchor and Chain Cable Act, 1967, applies to chain cables used on ships registered in the United Kingdom.

The tests detailed in 810 are to be applied.

Each length of chain is to be carefully examined after proof loading and is to be free from significant defects.

- 810 (a) Proof Loading Test. Each length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table P 8.3 for the appropriate grade and size of cable.
- (b) Breaking Test. Breaking test specimens are to be taken as required by Table P 8.2 and are to withstand the load given in Table P 8.3 for the appropriate grade and size of cable. The specimen shall be considered to have passed this test if it has shown no sign of fracture after application of the required load.

Where a breaking test specimen fails, a further specimen is to be cut from the same length of cable and subjected to test. If this retest fails, the length of cable from which it was taken is to be rejected. When this test is also representative of other lengths, each of the remaining lengths is to be individually tested by taking a breaking test specimen from each length of the batch.

For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

(c) MECHANICAL TESTS. For Grade U 3 chain cable, 1 tensile and 2 sets of 3 impact test pieces are to be taken from every four or less 27,5 m (15 fathom) lengths of cable,

The test pieces for the tensile and 1 set of the impact test pieces are to be taken clear of the weld, the remaining impact test pieces are to have the notch positioned at the weld centre.

Test pieces are not to be selected from the same length as that from which the breaking test sample has been taken unless breaking test samples have been taken from every length of the batch.

The results of these tests are to comply with the requirements given in Table P 8.1.

811 SHACKLES. End and joining shackles are to be subjected to the breaking and proof loads appropriate to the grade of cable for which they are intended. The breaking load shall be applied to at least one shackle out of 25 (1 in 50 for lugless shackles) and this item is to be destroyed and not used as part of an outfit.

Drop forged, cast steel and lugless shackles are to be manufactured to an agreed specification and tensile and impact or bend tests taken. The test samples are to be subjected to the same heat treatment as the shackles.

- *812 ATTACHMENT LINKS, ADAPTOR PIECES, ETC., are to be subjected to the breaking and proof loads appropriate to the grade of cable for which they are intended. The breaking load is to be applied to 1 item out of every 25 (or less) and this item is to be destroyed and not used as part of an outfit. Where, however, the items are of increased dimensions, and have been specially approved, the breaking load may be applied to each item and the item so tested included with the outfit.
- 813 Swivels are to be tested as required by 812 but the breaking load is to be applied to 1 out of every 7 (or less) unless made of increased dimensions.
- 814 All items subjected to the breaking load are to be destroyed and not used in the outfit except as specifically permitted by 812 and 813 for items of increased dimensions.

TABLE P 8.1

Designation	Method of	TENSIL	E RANGE	Elongation (on 5D)	Impact	Maximum
Designation	Manufacture	kg/mm ²	ton/in2	Minimum %	Minimum	Diameter of Former
Wrought Iron Grade 1(a)	Fire welded	31-41	19 • 7 – 26 • 0	30		1T
Mild Steel Grade 1(b) U 1(a) U 1(b)	Fire welded Flash-butt welded	31-41 31-41 41-50	$19 \cdot 7 - 26 \cdot 0 \\ 19 \cdot 7 - 26 \cdot 0 \\ 26 \cdot 0 - 31 \cdot 7$	30 30 25		1T 1T 2T
Special Quality Grade U 2(a) U 2(b)	Flash-butt welded or drop forged Cast Steel	50–65 50 min.	31·7-41·3 31·7 min.	22 22		3T 3T
Extra Special Quality Grade U 3(a)	Flash-butt welded or drop forged	70 min.	44·4 min.	17	*6 kg m (43·5 ft lb) at 0°C clear of weld *5 kg m (36·2 ft lb) at 0°C in way of weld	_
U 3(b)	Cast Steel	70 min.	44·4 min.	17	*6 kg m (43·5 ft lb) at 0°C	-

Notes: (1) T is equal to the diameter or thickness of the bend test piece.
(2) For Grade U 3 cable, minimum reduction of area see 807(c)
(3) Except where otherwise stated Grades 1(a) and 1(b) are to comply with all the requirements for Grade U 1(a) not heat treated.

* Average value from 3 test specimens.

TABLE P 8.2—NUMBER OF BREAKING TESTS

Designation	Method of Manufacture	Number of Breaking Test Specimens
Grade 1(a) 1(b)	Fire welded	One from each length of 27,5 m (15 fathoms) or less
Grade U 1 U 2(a) U 3(a)	Flash-butt welded, or drop forged, and heat treated	One from every four lengths of 27,5 m (15 fathoms) or less
Grade U 1	Flash-butt welded but not heat treated	One from each length of 27,5 m (15 fathoms) or less
Grade U 2(b) U 3(b)	Cast and heat treated	One per heat treatment batch with a minimum of one from every four lengths of 27,5 m (15 fathoms) or less

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TABLE P 8.3-STUD LINK CHAIN CABLE

			GF	LADE				n weight per
Chain Diameter	U	1		J 2		U 3	- Jength	of 27,5 m
	Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load	With Dee Shackle	With Lugle Shackle
mm	kg	kg	kg	kg	kg	kg	kg	kg
12,5	4700	6700	6700	9400	9400	13 500	107	105
14	5900	8400	8400	11 800	11 800	16 800	130	127
16	7700	10 900	10 900	15 300	15 300	22 000	160	157
17,5	9100	13 000	13 000	18 300	18 300	26 100	190	186
19	10 700	15 300	15 300	21 500	21 500	30 700	220	216
20,5	12 500	17 800	17 800	24 900	24 900	35 600	252	248
22	14 300	20 400	20 400	28 600	28 600	40 900	290	286
24	17 000	24 200	24 200	33 900	33 900	48 500	350	345
26	19 800	28 300	28 300	39 700	39 700	56 700	410	405
28	22 900	32 700	32 700	45 800	45 800	65 500	480	475
30	26 200	37 500	37 500	52 400	52 400	74 900	550	545
32	29 700	42 500	42 500	59 400	59 400	84 900	620	615
34	33 400	47 700	47 700	66 800	66 800	95 500	700	690
36	37 300	53 300	53 300	74 600	74 600	107 000	785	775
38	41 400	59 200	59 200	82 800	82 800	118 000	875	860
40	45 700	65 300	65 300	91 400	91 400	131 000	965	950
42	50 200	71.700	71 700	100 000	100 000	143 000	1055	1040
44	54 900	78 400	78 400	110 000	110 000	157 000	1150	1130
46	59 700	85 300	85 300	119 000	119 000	171 000	1260	1240
48	64 800	92 600	92 600	130 000	130 000	185 000	1370	1345
50	70 000	100 000	100 000	140 000	140 000	200 000	1485	1455
52	75 400 81 000	108 000 116 000	108 000	151 000	151 000	215 000	1605	1575
54 56	86 800	124 000	116 000	162 000	162 000 174 000	231 000	1725	1690
58	92 700	132 000	124 000 132 000	174 000 185 000	185 000	248 000 265 000	1850	1810
60	98 800	141 000	141 000	198 000	198 000	282 000	1985 2125	1945 2075
62	105 000	150 000	150 000	210 000	210 000	300 000	2275	2220
64	112 000	159 000	159 000	223 000	223 000	319 000	2430	2370
66	118 000	169 000 -	169 000	236 000	236 000	337 000	2590	2525
68	125 000	178 000	178 000	250 000	250 000	357 000	2755	2685
70	132 000	188 000	188 000	263 000	263 000	376 000	2925	2850
73	142 000	203 000	203 000	285 000	285 000	407 000	3185	3100
76	153 000	219 000	219 000	307 000	307 000	438 000	3460	3360
78	161 000	230 000	230 000	322 000	322 000	459 000	3640	3535
81	172 000	246 000	246 000	345 000	345 000	492 000	3940	3820
84	184 000	263 000	263 000	368 000	368 000	526 000	4240	4105
87	196 000	280 000	280 000	393 000 .	393 000	561 000	4555	4405
90	209 000	298 000	298 000	417 000	417 000	596 000	4870	4705
92	217 000	310 000	310 000	434 000	434 000	620 000	5085	4905
95	230 000	329 000	329 000	460 000	460 000	657 000	5405	5210
97	239 000	341 000	341 000	477 000	477 000	682 000	5630	5425
100	252 000	360 000	360 000	504 000	504 000	720 000	5970	5745
102	261 000	373 000	373 000	522 000	522 000	746 000	6210	5970
105	275 000	393 000	393 000	550 000	550 000	785 000	6580	6320
107	284 000	406 000	406 000	568 000	568 000	812 000	6845	6575
111	303 000	433 000	433 000	606 000	606 000	865 000	7380	7080
114	317 000	453 000	453 000	635 000	635 000	907 000	7795	7475
117	332 000	474 000	474 000.	664 000	664 000	948 000	8220	7870
120	347 000	495 000	495 000	694 000	694 000	991 000	8650	8270
122	357 000	510 000	510 000	714 000	714 000	1 019 000	8960	8550
124	367 000	524 000	524 000	734 000	734 000	1 048 000	9275	8835
127	382 000	546 000	546 000	764 000	764 000	1 092 000	9740	9270
130	398 000	568 000	568 000	795 000	795 000	1 136 000	10 210	9710
132	408 000	583 000	583 000	816 000	816 000	1 165 000	10 540	10 005
137	434 000	620 000	620 000	868 000	868 000	1 240 000	11 320	10 750
142	461 000	658 000	658 000	921 000	921 000	1 316 000	12 110	11 500
147	488 000	697 000	697 000	975 000	975 000	1 393 000	12 950	12 300
152	515 000	736 000	736 000	1 030 000	1 030 000	1 471 000	13 890	13 200

TABLE P 8.3-STUD LINK CHAIN CABLE

			GR	ADE			Minimum	weight per 15 fathoms
Chain Diameter	U	1	U	1 2	Ţ	J 3	length of	15 fathoms
	Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load	With Dee Shackle	With Lugle Shackle
Inches	Tons	Tons	Tons	Tons	Tons	Tons	Cwt	Cwt
1	4.77	6.82	6.82	9.55	9.55	13.64	21	2 1
9	6.03	8.61	8.61	12.05	12.05	17.22	25	
5 8	7.42	10.60	10.60	14.83	14.83	21.19	31	2 % 3 % 3 % 4 % 5 %
븅	8.95	12.78	12.78	17.90	17.90	25.57	3 5	3 %
3	10.62	15 - 17	15.17	21 - 24	$21 \cdot 24$	30.34	43	4 16
13	12.43	17.75	17.75	24 · 85	24.85	35.50	51	5 16
7	$14 \cdot 36$	20.52	20.52	28.73	28.73	41.00	57	51
15	16.44	23.49	23.49	32.88	32.88	46.97	63	6 5
1	18.65	26.65	26-65	37.30	37 - 30	53.30	75	71
11	23.50	33.50	33.50	46.90	46.90	67.00	93	95
1 16	26.05	37 - 25	$37 \cdot 25$	52 · 10	52.10	74 · 45	107	103
11	28.80	41.15	41 · 15	57.60	57.60	82 · 25	12	117
1 15	31.65	45.20	45.20	63.30	63.30	90.40	134	13 1
1 7	37.70	53.90	53.90	75 · 45	75 - 45	107-80	157	15 ₩
11	40.95	58.50	58.50	81.90	81.90	117.00	171	17
1 %	44.30	63.30	63.30	88-60	88 · 60	126.60	184	181
1 5	$47 \cdot 75$	68 · 25	68 · 25	95.50	95.50	136 · 45	20	195
11	55.05	78.65	78 - 65	110.10	110.10	157 · 25	231	223
1 13	58.85	84 · 10	84.10	117.70	117.70	168 · 15	247	241
17	62.80	89.70	89.70	125.60	125.60	179 - 40	26 \$	261
2	71.00	101 · 40	101.40	142.00	142.00	202 · 85	30	293
2 16	$75 \cdot 26$	107 - 51	107.51	150.50	150.50	215.00	317	311
21	79.63	113.75	113.75	159.25	159 - 25	227.50	331	33
2 1	84.10	120.15	120.15	168 · 25	168 · 25	240.30	357	351
2 5	93.40	133 · 45	133 - 45	186.80	186 - 80	266 · 85	40	391
23	98 · 20	140.30	140.30	196 - 40	196 · 40	280.55	424	411
2 7	103.10	147.30	147.30	206.20	206-20	294.55	441	433
21/2	108 · 10	154 · 45	154 · 45	216.20	216 - 20	308.85	47	457
25	118 · 40	169.15	169 - 15	236.80	236 · 80	338 · 30	52	50 \$
2 11	123.70	176.70	176.70	247 - 40	247 - 40	353 · 40	541	531
23	129.10	184 · 40	184 · 40	258 · 20	258 · 20	368 · 85	571	55 §
27	140.15	200 · 25	200 · 25	280.35	280.35	400.45	625	607
3	151.60	216.60	216.60	303 · 20	303 · 20	433 - 15	683	663
3 16	157 · 45	224 · 95	$224 \cdot 95$	314.90	314.90	449.85	711	691
3 3	169 - 40	242.05	242.05	338 · 85	338 · 85	484.05	77%	75
3 16	181 - 75	259 - 60	259.60	363 · 45	363 · 45	519 - 25	83 \$	81
3 7	194.35	277 · 70	277 - 70	388 - 75	388 - 75	555 - 35	901	871
3 %	207 - 35	296 - 20	296 · 20	414.65	414.65	592 · 35	961	931
35	213.95	305 · 60	305 - 60	427.85	427 · 85	611 · 25	100	931
34	227 - 35	324 · 80	324.80	454.70	454 · 70	649.55	106 \$	1021
3 13	$234 \cdot 64$	335 · 25	335 - 25	469.33	469 · 33	670.50	$110\frac{7}{8}$	$106\frac{3}{4}$
3 15	248.05	354 · 33	$354 \cdot 33$	496.06	496.06	708 · 65	$116\frac{3}{4}$	$112\frac{1}{2}$
4	255.05	364 · 35	364 - 35	510.15	510.15	728.75	$120\frac{5}{8}$	116
$4\frac{1}{8}$	269.35	384.75	$384 \cdot 75$	538 · 65	538 - 65	769 - 50	$128\frac{5}{8}$	$123\frac{1}{2}$
4 7	277.89	397.00	397.00	555.77	555 - 77	793 · 95	$134\frac{3}{4}$	$129\frac{3}{8}$
$4\frac{3}{8}$ $4\frac{1}{2}$	298 - 65	426 - 65	426.65	597 · 30	597 - 30	853 · 25	$145\frac{3}{8}$	1398
41/2	313.70	448.10	448.10	627 - 35	$627 \cdot 35$	896 - 20	1541	1475
45	328 - 90	469 - 90	469.90	657 · 85	657.85	939.80	163	156
43	344.40	492.00	492.00	688.80	688 · 80	984.00	172	1641
43 4 13	$351 \cdot 25$	501.78	501.78	702 · 49	702 · 49	1000.36	1765	1688
478	361.01	515.73	515.73	722.03	722.03	1031 · 47	$182\frac{1}{8}$	1731
5	376.02	537 · 18	537 · 18	752.06	752.06	$1074 \cdot 36$	$191\frac{5}{8}$	$182\frac{1}{2}$
$5\frac{1}{8}$	391 - 21	558 - 87	558.87	782 - 42	782 · 42	1117 · 74	2013	$191\frac{1}{2}$
5 16	401 · 42	573 · 45	573 - 45	802.83	802 · 83	1146 · 91	207	$196\frac{1}{2}$
$5\frac{3}{8}$	$427 \cdot 23$	610.33	610.33	854 · 46	854 · 46	1220.66	2223	$211\frac{1}{8}$
5%	453.43	647 · 75	647 - 75	906 · 85	906 - 85	1295.51	$237\frac{3}{8}$	$225\frac{1}{2}$
53	479.96	685 · 66	685 · 66	959 · 93	959 · 93	1371 · 34	$253\frac{7}{8}$	241
6	506.80	724.00	724.00	1013 · 61	1013 · 61	1448.01	2741	2601

LLOYD'S REGISTER OF SHIPPING

TABLE P 8.4—SHORT LINK CHAIN CABLE

		GRA	ADE			weight per
Diameter	U	1	, ,	J 2	length o	d 27,5 m
	Proof Load	Breaking Load	Proof Load	Breaking Load	Forged	Electric Welded
mm	kg	kg	kg	. kg	kg	kg
11	2250	4500	3150	6300	100	60
12	2700	5400	3800	7600	115	75
13	3200	6400	4500	9000	130	95
14	3650	7300	5200	10 400	145	115
15	4200	8400	5950	11 900	160	135
16	4800	9600	6750	13 500	175	155
17	5450	10 900	7650	15 300	195	175
18	6100	12 200	8600	17 200	215	195
19	6800	13 600	9550	19 100	240	215
20	7550	15 100	10 600	21 200	265	235
21	8300	16 600	11 700	23 400	290	260
22	9100	18 200	12 800	25 600	315	285
23	9950	19 900	14 000	28 000	345	310
24	10 900	21 700	15 300	30 500	375	340
25	11 800	23 600	16 600	33 100	405	370
26	12 800	25 500	17 900	35 800	440	400
27	13 700	27 400	19 300	38 500	475	435
28	14 800	29 500	20 800	41 500	510	470
29	15 900	31 700	22 300	44 500	545	505
30	17 000	34 000	23 900	47 700	580	540
31	18 200	36 300	25 500	50 900	620	575
32	19 400	38 700	27 100	54 200	655	615
33	20 600	41 100	28 900	57 700	695	650
34	21 800	43 600	30 600	61 200	740	690
35	23 100	46 200	32 400	64 800	785	730
36	24 500	48 900	34 300	68 600	830	770
37	25 900	51 700	36 300	72 500	875	810
38	27 300	54 600	38 200	76 400	920	855
39	28 800	57 500	40 300	80 500	970	905
40	30 200	60 400	42 300	84 600	1020	955
41	31 700	63 400	44 500	89 000	1070	1005
42	33 300	66 600	46 700	93 400	1125	1055
43	34 900	69 800	49 000	97 900	1180	1105
44	36 600	73 200	51 300	102 000	1240	1155
45	38 300	76 500	53 600	107 000	1300	1205
46	39 900	79 900	56 000	112 000	1360	1260
47	41 700	83 400	58 200	117 000	1425	1315
48	43 500	87 000	61 000	122 000	1490	1370
49	45 400	90 700	63 500	127 000	1555	1430
50	47 300	94 500	66 200	132 000	1625	1490
51	49 200	98 300	68 800	138 000	1695	1555

or in British units:-

TABLE P 8.4—SHORT LINK CHAIN CABLE

		GF	LADE		Minimum weight per		
Diameter	U	1	U	1 2	length of	15 fathoms	
ON OF SAN	Proof Load	Breaking Load	Proof Load	Breaking Load	Forged	Electric Welded	
Inches	Tons	Tons	Tons	Tons	Cwt	Cwt	
7	2 · 25	4.50	3.20	6.40	2.0	1.5	
1	3.00	6.00	4.20	8 • 40	2.5	1.9	
16	3.75	7.50	5.30	10.60	3.0	2.4	
i	4.65	9.25	6.55	13.10	3.5	3.0	
#	5.65	11.25	7.95	15.90	4.0	3.6	
3	6.75	13.50	9.45	18.90	4.8	4.3	
18	7.90	15.80	11.10	22.20	5.5	5.0	
7	9.15	18.25	12.85	25.70	6.4	5.8	
18	10.50	21.00	14.75	29.50	7.3	6.7	
1	12.00	24.00	16.80	33.60	8.3	7.6	
1 16	13.50	27.00	18.95	37.90	9.3	8.6	
11	15.15	30.25	21.25	42.50	10.4	9.6	
1 10	16.90	33.80	23.70	47.40	11.6	10.7	
11/4	18.75	37.50	26 · 25	52.50	12.9	11.8	
1 16	20.65	41.25	28.95	57.90	14.1	13.0	
1 1	22.65	45.25	31.75	63.50	15.5	14.3	
1 7/16	24.75	49.50	34.70	69.40	17.0	15.6	
$1\frac{1}{2}$	27.00	54.00	37.80	75.60	18.4	17.0	
1 %	29.25	58.50	41.00	82.00	19.9	18.4	
1 5	31.65	63 · 25	44.35	88.70	21.5	19.9	
1 118	34 · 15	68 • 25	47.85	95.70	23 · 1	21.5	
134	36.75	73.50	51.45	102.90	25.0	23.1	
1 13	39.40	78.80	55.20	110-40	26.9	24.8	
17	42.15	84.25	59.05	118-10	28.9	26.5	
1 15	45.00	90.00	63.05	126 - 10	30.9	28.3	
2	48.00	96.00	67 - 20	134.40	33.0	30.2	

Section 9

STEEL WIRE ROPES FOR STANDING RIGGING, TOWLINES AND MOORING ROPES

Note. For list of manufacturers of steel wire ropes see Appendix following Chapter Q.

Approval of Works

901 The manufacturer's plant and method of production are to be approved by the Committee. The works are to be at all times open to inspection of the Surveyor and periodical inspections are to be held at intervals not exceeding two years.

Each manufacturer is required to provide on his premises machines suitable for satisfactorily making the prescribed tests. The tensile testing machine is to be of an approved type and is to be calibrated at intervals not exceeding two years. Alternatively, tests carried out by a competent government, municipal or similar responsible body will be accepted.

Material

902 The wire used in the manufacture of the rope is to be drawn from steel made by the open hearth, electric

furnace or oxygen process, or by other process approved by the Committee and is to be of homogeneous quality, consistent strength and free from visual defects likely to impair the performance of the rope. The tensile strength of the wire should generally be within the ranges 130-160 kg/mm² (80-100 ton/in²) or 160-180 kg/mm² (100-115 ton/in²).

Galvanizing

903 The wire is to be galvanized by the hot dip or the electrolytic process to give a continuous uniform coating complying with the test requirements specified in 909 and 910. The coating may be any of the following grades:—

Grade 1-Heavy coating, drawn after galvanizing.

Grade 2-Heavy coating, finally galvanized.

Grade 3-Light coating, drawn after galvanizing.

Construction of Ropes

904 The construction of wire ropes for standing rigging, towlines and mooring ropes is generally to be as given in Table P 9.1 but alternative types of wire rope will be specially considered on the basis of an equivalent breaking load and the suitability of the construction for the purpose intended.

TABLE P 9.1

Purpose		Construc	tion of Rope	Construction of
20-61	Strands	Wires	Core	Strands
Standing rigging	6	7	Fibre	6 over 1
	6 7 7	7	Wire	6 over 1
	7	19	Wire	12 over 6 over 1
	7	37	Wire	18 over 12 over 6 over 1
Mooring ropes	6	19	Fibre	12 over 6 over 1
and towlines	6	24	Fibre	15 over 9 over fibre core
	6	37	Fibre	18 over 12 over 6 over 1
	6	26	Fibre	10 over (5 + 5) over 5 over 1
	- 6	31	Fibre	12 over (6 + 6) over 6 over 1
	6	36	Fibre	14 over (7 + 7) over 7 over 1
	6	41	Fibre	16 over (8 + 8) over 8 over 1
	6	30	Fibre	18 over 12 over fibre core
	6	54	Fibre	24 over 18 over 12 over fibre core
	6	61	Fibre	24 over 18 over 12 over 6 over 1
	6	42	Fibre	$6 \times (6 \text{ over 1}) \text{ over fibre core}$
Mooring ropes				
and towlines	6 .	31	7 × 7 Wire Rope	12 over (6 + 6) over 6 over 1
used in	6	36	7 × 7 Wire Rope	14 over (7 + 7) over 7 over 1
association	- 6	41	7 × 7 Wire Rope	16 over (8 + 8) over 8 over 1
with mooring winches		2 2		

Note. See Table D 34.1, Notes 3 and 4.

Tests

905 A sample of the completed rope shall be subjected to a breaking test to destruction. The sample shall be of sufficient length to provide a clear test length of at least 36 times the rope diameter. Not more than four-fifths of the nominal breaking load may be applied quickly and thereafter the load is to be applied slowly and steadily until the maximum load is obtained.

Tests in which a breakage occurs adjacent to the grips may, at the option of the manufacturer, be neglected.

The actual breaking load is not to be less than that given in an appropriate national standard.

906 If facilities are not available for making a breaking test on completed ropes intended for standing rigging or mooring ropes, consideration will be given to the acceptance of the determination of the breaking load by the summation of the tests of individual wires and the deduction of a percentage for laying up. This percentage is not to be less than that given in Table P 9.2. Manufacturers desiring to adopt this method of testing may be required to arrange for check breaking tests to be carried out on completed ropes.

TABLE P 9.2

CONSTRUCTION OF ROPE	PERCENTAGE DEDUCTION
6× 7	10
6×19	13
6×24	13
6×37	17,5
7× 7	15
7×19	18
7×37	22,5

NOTE. Percentage deductions for other constructions should either be in accordance with a recognized national standard or are to be established by breaking tests carried out on completed ropes.

907 A suitable length shall be cut off the rope, unstranded and straightened, and six wires subjected to a torsion test (see 908) and six wires to a wrap test for adhesion of coating (see 910).

Alternatively, these tests may be carried out on the wire before the rope is stranded.

Torsion Test

908 The length of sample shall be such as to allow a distance between the grips of 100 times the diameter of wire, but this distance need not exceed 300 mm (12 in). The wire is to be twisted by causing one or both of the vices to be revolved until fracture occurs. The speed of testing should not exceed, for a length equal to 100 times the diameter, that given in Table P 9.3.

(A tensile load not exceeding 2 per cent of the breaking load of the wire may be applied to keep the wire stretched.)

The wire shall withstand, on a length of 100 times the diameter of wire, the number of complete twists given in Table P 9.4.

Weight and Uniformity of Zinc Coating

909 The weight of coating shall comply with the minimum figures shown in Table P 9.5 when tested in accordance with a recognized standard.

The uniformity of the zinc coating is to be tested by a dip test, carried out in accordance with a recognized standard.

Wrap Test for Adhesion of Coating

910 The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for ten complete turns of wrap. The ratio between the diameter of the mandrel and that of the wire is to be as in Table P 9.6.

After winding on the appropriate mandrel the zinc coating should neither have flaked nor cracked to such an extent that any zinc can be removed by rubbing with the bare fingers.

TABLE P 9.3

	Diameter of				
m	m	In	ich	Maximum Speed of Testin Turns per Minute	
From (Including)	Up to (Excluding)	From (Including)	Up to (Excluding)	Turns per minute	
1,5 3,0	1,5 3,0 5,0	0·06 0·12	0·06 0·12 0·20	90 60 30	

TABLE P 9.4

	Diameter of	Coated Wire		Number of Twists				
mm		In	ich	Gra	de 2	Grade	1 or 3	
From (Including)	Up to (Excluding)	From (Including)	Up to (Excluding)	Tested Before Stranding	Tested After Stranding	Tested Before Stranding	Tested After Stranding	
	1,3		0.051	15	13	27	24	
1,3	2,3	0.051	0.090	15	13	26	23	
2,3	3,0	0.090	0.118	14	12	23	20	
3,0	4,0	0.118	0.157	12	10	21	18	

Certificates

911 Printed forms of certificates, approved by the Committee, are to be signed by the manufacturers and will be supplied to them on application.

TABLE P 9.5

Diameter of Coated Wire		Coating	
mm		Grade 1 or 2	Grade 3
From (Including)	Up to (Excluding)	gm/m²	gm/m³
0,40	0,50	75	40
0,50	0,60	90	. 50
0,60	0,80	110	60
0,80	1,00	130	70
1,00	1,20	150	80
1,20	1,50	165	90
1,50	1,90	180	100
1,90	2,50	205	110
2,50	3,20	230	125
3,20	4,00	250	135

or in British units:-

TABLE P 9.5

Diameter of	Diameter of Coated Wire		ing
In	ch	Grade 1 or 2	Grade 3
From (Including)	Up to (Excluding)	oz/ft²	oz/ft²
0.016	0.020	0.25	0.13
0.020	0.024	0.30	0.17
0.024	0.031	0.36	0.20
0.031	0.039	0.43	0.23
0.039	0.047	0.50	0.26
0.047	0.059	0.55	0.30
0.059	0.075	0.60	0.33
0.075	0.098	0.68	0.36
0.098	0.126	0.76	0.41
0.126	0.157	0.82	0.45

TABLE P 9.6

Coati	ng	Wire diameter less than 1,5 mm (0.059 in)	Wire diameter 1,5 mm (0°059 in) and over
Grade 1 or 2	1.0	 4	6
Grade 3		 2	3

Section 10

FIBRE ROPES

General

1001 Fibre ropes intended as mooring ropes may be made of coir, hemp, manilla or sisal or may be composed of synthetic (man-made) fibres. They may be either 3-strand (hawser laid) 4-strand (shroud laid) or 9-strand (cable laid) but other constructions will be specially considered.

1002 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognized national standard.

1003 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognized standard.

1004 Weighting and loading matter is not to be added and any added lubricant is to be kept to a minimum. Any rot-proofing or water repellancy treatment shall not be deleterious to the fibre nor shall it add to the weight or reduce the strength of the rope.

Testing

1005 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

1006 The minimum length of sample to be used in determining the breaking load of a fibre rope is to be as given in Table P 10.1. The specimen is to be loaded to the initial load, given in the Table as a percentage of the specified

breaking load, and checked for diameter and evenness of lay-up. The load is then to be increased evenly and continuously at the rate shown in the Table until the specimen breaks.

If the sample is held by grips and the break occurs within 150 mm (6 in) of the grips the test may be repeated but not more than two tests may be made on any one coil.

TABLE P 10.1—TESTING OF FIBRE ROPES

Material	Test	Initial	Speed of I	coading to
Material	mm (in)	Loading	Metres per minute	Inches per minute
Natural Fibre	1800 (72)	2%	0,15 ± 0,05	6 ± 2
Synthetic Fibre	900 (36)	1%	0,10 maximum	4 maximum

1007 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope the Society will consider alternative methods of testing.

Breaking Load

1008 The actual breaking load is not to be less than that given in an appropriate national standard,

Certificates

1009 Printed certificates issued by the manufacturer or a competent government, municipal or similar responsible body will be accepted. The certificate should give the breaking load, test length and speed of testing.

Section 11

APPROVAL OF ELECTRODES AND COMBINATIONS OF CONSUMABLES FOR WELDING IN HULL CONSTRUCTION

1101 The manufacturer's plant and method of production of electrodes and fluxes are to be such as to ensure reasonable uniformity in manufacture.

1102 Electrodes and wire-flux combinations will be approved subject to compliance with the following tests. The test pieces are to be prepared in the presence of the Surveyor and all tests carried out under his supervision.

ELECTRODES FOR MANUAL ARC WELDING

1103 Electrodes will be divided into Grades 1, 2 and 3 dependent on the results of the Charpy tests. In addition, if Grade 2 or Grade 3 electrodes comply with the require-

ments of the hydrogen test as given in 1114, a suffix H will be added to the Grade mark.

Electrodes which have satisfied the requirements of Grade 2 will also be considered as complying with Grade 1 requirements and those which have satisfied the requirements of Grade 3 will be considered as complying with Grades 1 and 2 requirements.

1104 Grade A hull structural steel may be used in the preparation of all test pieces, but at the option of the manufacturer Grades B, C or D steel may be used for Grade 2 electrode test pieces and Grade E steel for Grade 3 electrode test pieces.

Where approval is required for the welding of higher tensile steel of Grades AH, DH or EH, it is recommended that the butt weld assemblies be prepared using the appropriate grade of higher tensile steel (see 1107).

1105 The welding current used is to be within the range recommended by the manufacturer and, where an electrode is stated to be suitable for both a.c. and d.c., a.c. is to be used for the preparation of the test assemblies.

Deposited Metal Tests

1106 Tensile and impact tests are to be made, under controlled conditions, on metal deposited from the electrodes.

Two all-weld-metal test assemblies are to be prepared in the downhand position as shown in Fig. P 11.1, one

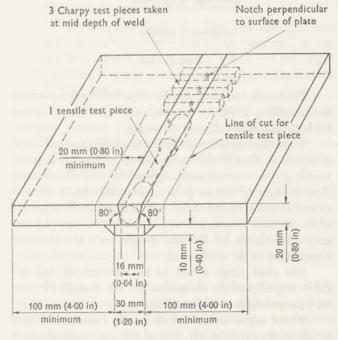


Fig. P 11.1

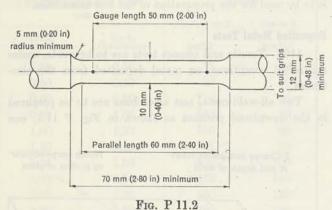
using 4 mm (8 S.W.G.) electrodes and the other using 8 mm ($\frac{5}{16}$ in) diameter electrodes or the largest size manufactured if this is less than 8 mm ($\frac{5}{16}$ in) diameter.

The weld metal is to be deposited in single or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm (0.08 in) and not more than 4 mm (0.16 in) thick. Between each run the assembly is to be left in still air until it has cooled to 250°C, the temperature being taken in the centre of the weld, on the surface of the seam.

After being welded the test assemblies are not to be subjected to any heat treatment.

Deposited Metal Tensile Tests

1107 The tensile test pieces, one from each all-weld-metal assembly, are to be machined to the dimensions shown in Fig. P 11.2, care being taken that the longitudinal axis coincides with the centre of the weld, and the mid-thickness of the plates.



The tensile test piece may be subjected to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

Where approval is required for the welding of mild steel of Grades A, D or E, the tensile strength of each test specimen is not to be less than 41 kg/mm² (26 ton/in²) nor more than 57 kg/mm² (36 ton/in²). Where this upper limit is exceeded special consideration will be given to the approval of the electrode, taking into consideration the other physical properties shown by the test results, and the chemical composition of the weld metal.

The yield stress is not to be less than 31 kg/mm² (19.6 ton/in²) and the elongation not less than 22 per cent on a gauge length of 50 mm (2 in).

Where approval is required for the welding of higher tensile steel of Grades AH, DH or EH the tensile strength is not to be less than 50 kg/mm² (32 ton/in²) nor more than

68 kg/mm² (43 ton/in²). Where this upper limit is exceeded special consideration will be given as above.

Alternatively, if the butt weld assemblies as required by 1109 are prepared using higher tensile steel of Grade AH, DH or EH as appropriate and provided the tensile strengths of the transverse tensile specimens as required by 1110 are not less than 50 kg/mm² (32 ton/in²) then the tensile strength of the deposited metal tensile test specimens may be lower than required above but must exceed 47 kg/mm² (30 ton/in²).

The yield stress of the deposited metal tensile test specimens is not to be less than 36 kg/mm² (23 ton/in²) and the elongation not less than 22 per cent on a gauge length of 50 mm (2 in).

Deposited Metal Impact Tests

1108 The impact test pieces are to be of the standard Charpy V-notch type in accordance with P 207, three test pieces being taken from each of the deposited metal test assemblies. The test pieces shall be cut with their longitudinal axes perpendicular to the weld and the upper surface 5 mm from the upper surface of the plate.

The notch shall be positioned in the centre of the weld and is to be cut in the face of the test piece perpendicular to the surface of the plate,

For Grade 1 electrodes the average impact value for the three specimens from each assembly shall not be less than 4,8 kg m (35 ft lb) at about 20°C. The corresponding value for Grade 2 electrodes is 4,8 kg m (35 ft lb) at 0°C and for Grade 3 electrodes 6,2 kg m (45 ft lb) at -10°C or 4,8 kg m (35 ft lb) at -20°C. The test temperature for Grades 2 and 3 test pieces is to be controlled to within ± 1 degC of the prescribed temperature. Both the test specimen and the handling tongs are to be cooled for a sufficient length of time to reach the test temperature and the specimen then quickly transferred from the cooling device to the anvil of the testing machine and broken within a time lapse of not more than 5 seconds.

If the average of the three Charpy specimens fails to comply with the above requirements by an amount not exceeding 15 per cent of the required value, three additional test pieces may be made and tested, and the results added to those previously obtained to form a new average, which must comply with the requirements.

When the average value of the three Charpy specimens is more than 15 per cent below the required value, then six more Charpy test pieces are to be prepared and the average value of these new test pieces is to comply with the requirements.

The individual values of the Charpy specimens should be reasonably uniform and, to this end, a set of three Charpy specimens which meets the required average but which contains one or more values below 3,2 kg m (24 ft lb) when testing at 20°C, 0°C and $-20^{\circ}\mathrm{C}$ or 4,2 kg m (30 ft lb) when testing at $-10^{\circ}\mathrm{C}$ shall be disregarded and a further set of three specimens prepared and tested in its place.

The requirements for higher tensile steel approval do not differ from those given above.

Butt Weld Tests

1109 Butt weld assemblies as shown in Fig. P 11.3 are to be prepared for each welding position (downhand, horizontal-vertical, vertical and overhead) for which the electrode is recommended by the manufacturer, except that electrodes satisfying the requirements for downhand and vertical positions will be considered as also complying with the requirements for the horizontal-vertical position.

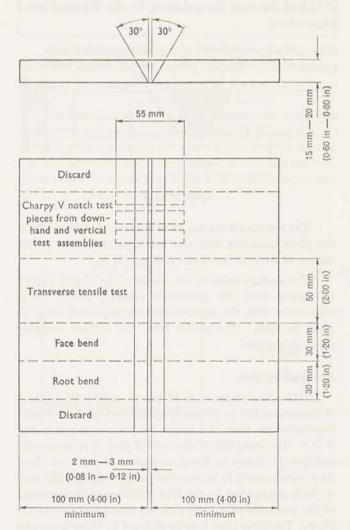


Fig. P 11.3

The test assemblies are to be made by welding together two plates 15 to 20 mm (0.60 to 0.80 in) in thickness not less than 100 mm (4 in) in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to form a single vee joint, the included angle between the fusion faces being 60° and the root gap being 2 to 3 mm (0.08 to 0.12 in).

Where the electrode is only to be approved in the downhand position an additional test assembly is to be prepared in that position.

The following welding procedure should be adopted in making the test assemblies:—

Downhand (a). First run with 4 mm (8 S.W.G.) electrode. Remaining runs (except last two layers) with 5 mm (6 S.W.G.) electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest size of electrode manufactured or 8 mm (5 in) whichever is the less.

Where a second downhand test is required:-

Downhand (b). First run with 4 mm (8 S.W.G.) electrode. Next run with an intermediate size electrode 5 mm (6 S.W.G.) or 6 mm (4 S.W.G.) and the remaining runs with the largest size of electrode manufactured or 8 mm ($\frac{5}{10}$ in) whichever is the less.

Horizontal-vertical. First run with 4 mm (8 S.W.G.) or 5 mm (6 S.W.G.) electrode. Subsequent runs with 5 mm (6 S.W.G.) electrodes.

Vertical and overhead. First run with 3,15 mm (10 S.W.G.) electrode. Remaining runs with 4 mm (8 S.W.G.) electrodes or possibly with 5 mm (6 S.W.G.) electrodes if this is recommended by the manufacturer for the positions concerned.

If the electrode being tested is specially intended for vertical welding in the downward direction, then this technique should be adopted for the preparation of the vertical butt weld assembly, using electrode diameters as recommended by the manufacturer.

In all cases the back sealing runs are to be made with 4 mm (8 S.W.G.) electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

The butts are to be welded using normal welding practice and between each run the assembly is to be left in still air until it has cooled to 250°C the temperature being taken in the centre of the weld, on the surface of the seam.

After being welded the test assemblies are not to be subjected to any heat treatment.

It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain any defects in the weld prior to testing.

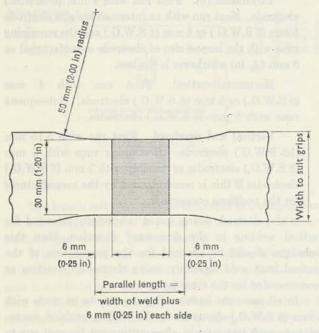
Each assembly shall then be cut to form one tensile, one face bend, and one root bend as shown in Fig. P 11.3, together with three Charpy specimens required from the downhand and vertical assemblies.

Butt Weld Tensile Tests

1110 Specimens of the form as shown in Fig. P 11.4 are to be prepared.

The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

The tensile strength of each test piece shall not be less than 41 kg/mm² (26 ton/in²), for the welding of mild steel Grade A, D or E, and 50 kg/mm² (32 ton/in²) for the welding of higher tensile steel Grade AH, DH or EH in cases where the deposited metal tensile strength is below 50 kg/mm² (32 ton/in²) and butt welded assemblies are prepared using the appropriate grade of higher tensile steel (see 1107).



Butt Weld Bend Tests

1111 The specimens are to be 30 mm $(1 \cdot 20 \text{ in})$ in width. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate and the sharp corners of the specimens rounded to a radius not exceeding 2 mm $(0 \cdot 08 \text{ in})$.

Fig. P 11.4

The test specimens are to be capable of withstanding, without fracture, being bent through an angle of 120° over a former having a diameter three times the thickness of the specimen.

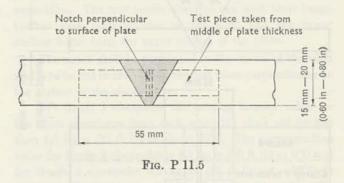
One specimen from each welded assembly is to be tested with the face of the weld in tension and the other with the root of the weld in tension.

The test pieces can be considered as complying with the test if, on completion of the test, no crack or defect, at the outer surface of the test specimen, can be seen.

Butt Weld Impact Tests

1112 Three Charpy V-notch impact test pieces are to be machined from each of the downhand and vertical test assemblies.

The test pieces are to be prepared as shown in Fig. P 11.5 of the same dimensions as for the deposited metal impact tests.



The test specimens are to be taken from the middle of the plate thickness with the notch perpendicular to the surface of the plate as shown in Fig. P 11.5.

The average value of the results of the Charpy impact test pieces from the downhand assembly are to be in accordance with the requirements for deposited metal as given in 1108. The results from the vertical assembly are to be reported.

Hot Cracking Test

1113 Two plates 12 to 15 mm (0.50 to 0.60 in) thick of dimensions 120 by 80 mm (5 by 3.25 in) are to be welded together in the form of a square tee joint as shown in Fig. P 11.6. The lower face of the vertical plate is to be straight and is to fit closely on the plane surface of the lower plate. Any unevenness is to be removed before welding. The tack welds in preparation for the fillet welds are to be positioned at the two ends on a level with the contact surface of the plates. The lower plate is to be stiffened by three transverse stiffeners in order to prevent distortion.

The fillet welding, which is to be made in one pass, is to be carried out in the downhand position and the welding current used is to be the maximum of the range recommended by the manufacturer for the size of electrode used.

The second fillet weld shall be started immediately after the completion of the first fillet weld and at the end of the specimen at which the first fillet weld finished. Both fillet welds are to be executed at a constant speed and without weaving.

For welding the full length of each fillet 120 mm (5 in) the following lengths of electrodes are to be fused:—

Diameter of Electrode	Length of Fused Electrode		
Diameter of Electrode	1st fillet	2nd fillet	
4 mm (8 S.W.G.)	200 mm (8 in)	150 mm (6 in)	
5 mm (6 S.W.G.)	150 mm (6 in)	100 mm (4 in)	
6 mm (4 S.W.G.)	100 mm (4 in)	75 mm (3 in)	

After welding, the slag is to be removed from the fillet welds and after complete cooling they are to be examined for cracks by a magnifying glass or by the use of penetrant fluids.

The first fillet weld is then to be cut out by machining or gouging and the second weld broken by closing the two plates together, subjecting the root of the weld to tension. The weld shall then be examined for evidence of hot cracking. There should be no cracking in the fillet welds (except crater cracks) either superficial or internal.

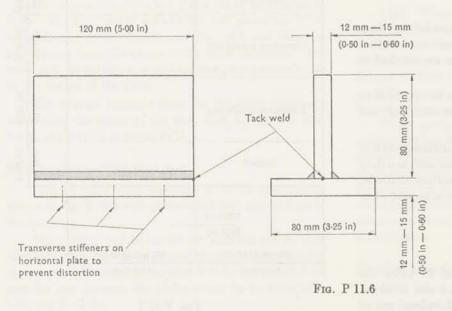
Hydrogen Test

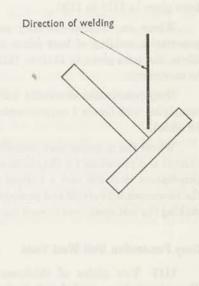
1114 Electrodes which have satisfied the requirements of Grade 2 or Grade 3 may, at the option of the manufacturer, be submitted to a hydrogen test, and a suffix H will be added to the Grade number to indicate compliance with the test requirements.

Four test specimens are to be prepared measuring 12 by 25 mm (0.5 by 1 in) in cross section by about 125 mm (5 in) in length. The parent metal may be any grade of shipbuilding steel and, before welding, the specimens are to be weighed to the nearest 0,1 gm. On the 25 mm (1 in) surface of each test specimen a single band of welding is to be deposited about 100 mm (4 in) in length by a 4 mm (8 S.W.G.) electrode, using about 150 mm (6 in) of the electrode. The welding is to be carried out with as short an arc as possible and with a current of about 150 amp.

The electrodes, prior to welding, can be submitted to the normal drying process recommended by the manufacturer.

Within thirty seconds of the completion of the welding of each specimen the slag is to be removed and the specimen quenched in water at approximately 20°C. After a further 30 seconds the specimens are to be cleaned and placed in an apparatus suitable for the collection of hydrogen by displacement of glycerine. The glycerine is to be kept at a temperature of 45°C during the test. All four specimens are to be welded and placed in the hydrogen collecting apparatus within 30 minutes.





The specimens are to be kept immersed in the glycerine for a period of 48 hours and, after removal, are to be cleaned in water and spirit, dried and weighed to the nearest 0,1 gm to determine the amount of weld deposited.

The amount of gas evolved is to be measured to the nearest 0,05 c.c. and corrected for temperature and pressure to 20°C and 760 mm Hg.

The amount of hydrogen in terms of cubic centimetres per gram of weld metal is to be reported and is not to exceed an average of 0,1 c.c. per gram for the four specimens tested.

Alternatively, the hydrogen content of the weld metal may be determined by any mercury gas burette type of apparatus, in accordance with a recognized procedure. Proposals for alternative methods of carrying out the test are to be submitted for approval.

Deep Penetration Electrodes

1115 Where, in addition to its use as a normal penetration electrode, a manufacturer desires to demonstrate that an electrode also has deep penetrating properties when used for downhand butt welding and horizontal-vertical fillet welding, the additional tests given in 1116 to 1120 are to be carried out.

Where a manufacturer recommends that an electrode having deep penetrating properties can also be used for downhand butt welding of thicker plates with prepared edges, the electrode will be treated as a normal penetration electrode and the full series of tests in the downhand position are to be carried out, together with the deep penetration tests given in 1116 to 1120.

Where an electrode is only recommended for deep penetration welding of butt joints and horizontal-vertical fillets, the tests given in 1116 to 1120 only are required to be carried out.

Deep penetration electrodes will only be approved as complying with Grade 1 requirements. The suffix D.P. will be added.

Where the manufacturer prescribes a different welding current and procedure for the electrode when used as a deep penetration electrode and a normal penetration electrode, the recommended current and procedure are to be used when making the test specimens in each case.

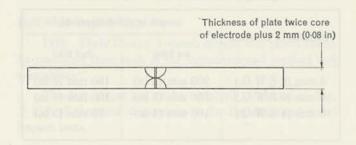
Deep Penetration Butt Weld Tests

1116 Two plates of thickness equal to twice the diameter of the core of the electrode plus 2 mm (0.08 in) are to be butt welded together with one downhand run of

welding from each side. The plates are not to be less than 100 mm (4 in) wide and of sufficient length to allow the cutting out of the test specimens of the correct number and size as shown in Fig. P 11.7.

The joint edges are to be prepared square and smooth and, after tacking, the gap is not to exceed 0.25 mm (0.01 in).

The test assembly is to be welded using an 8 mm ($\frac{5}{10}$ in) diameter electrode or the largest size manufactured if this is less than 8 mm ($\frac{5}{10}$ in).



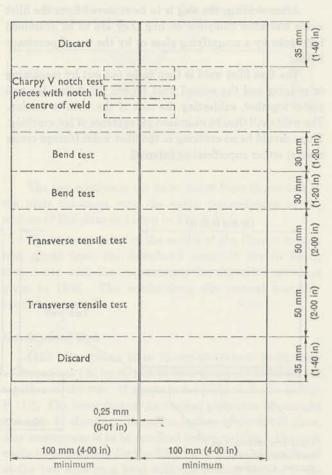


Fig. P 11.7

After welding, the test assembly shall be cut to form two transverse tensile test pieces, two bend test pieces and three Charpy V-notch impact test pieces.

The discards at the end of the welded assemblies are to be not more than 35 mm ($1 \cdot 4$ in) wide. The joints of these discards are to be polished and etched and must show complete fusion and interpenetration of the welds. At each cut in the test assembly the joints are also to be examined to ensure that complete fusion has taken place.

Deep Penetration Transverse Butt Weld Tensile Test

1117 Two transverse butt weld tensile test specimens are to be prepared to the dimensions given in Fig. P 11.4.

The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

The ultimate tensile strength of the test piece shall not be less than 41 kg/mm² (26 ton/in²).

Deep Penetration Butt Weld Bend Tests

1118 Two butt weld bend tests are to be prepared in accordance with the requirements of 1111 and are to be capable of withstanding, without fracture, being bent through an angle of 120° over a former having a diameter three times the thickness of the specimen.

One test piece shall be tested with the side first welded in tension and one with the other side in tension.

Deep Penetration Butt Weld Impact Tests

1119 Three Charpy V-notch impact test pieces are to be prepared, the notch being in the centre of the weld.

The dimensions of the test pieces are to be as given in 1108. The longitudinal axes of the test pieces are to be perpendicular to the direction of the weld, and they are to be taken from the centre of the plate thickness. The notch is to be cut in the face of the test piece perpendicular to the surface of the plate.

The average impact values for the three specimens taken from the centre of the weld shall not be less than 4,8 kg m (35 ft lb) at about 20°C.

Deep Penetration Fillet Weld Test

1120 A fillet weld assembly is to be prepared as shown in Fig. P 11.8 with plates about 12,5 mm (0·5 in) in thickness.

The welding shall be carried out with one run for each fillet with plate A in the horizontal plane during the welding operations. The length of the fillet is to be 160 mm (6.5 in) and the gap between the plates is not to be more than 0.25 mm (0.01 in).

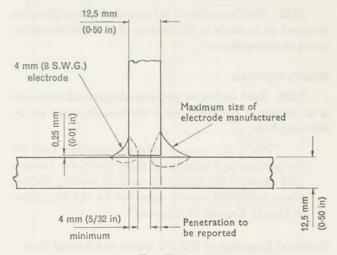


Fig. P 11.8

The fillet weld on one side of the assembly shall be carried out with a 4 mm (8 S.W.G.) electrode and that on the other side with the maximum size of electrode manufactured. The welding current used is to be within the range recommended by the manufacturer and the welding is to be carried out using normal welding practice.

The welded assembly shall be cut by sawing or machining within 35 mm (1·4 in) of the ends of the fillet welds and the joints are to be polished and etched. The welding of the fillet made with a 4 mm (8 S.W.G.) electrode is to show a penetration of 4 mm ($_{3\frac{5}{2}}$ in) (see Fig. P 11.8) and the corresponding penetration of the fillet made with the maximum size of electrode manufactured is to be reported.

Gravity Welding and Contact Welding

1121 Where an electrode is submitted solely for approval for use in contact welding using automatic gravity or similar welding devices, the first approval testing should consist of deposited metal, butt weld and hot cracking tests similar to those for normal manual electrodes carried out using the process for which the electrode is recommended by the manufacturer.

Where an electrode is submitted for approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, then the first approval testing is to be carried out as required by the Rules for manual arc welding. A hot cracking test, from which a macrograph should be taken, is also to be carried out using the gravity or other contact device as recommended by the manufacturer.

Chemical Analysis

1122 The chemical analysis of the weld metal made by the electrode is to be supplied by the manufacturer.

1123 The Committee is to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval.

Maker's Certificate

1124 Each carton or package of approved electrodes is to contain a certificate from the manufacturer on the following lines:—

Periodical Inspection of Maker's Works and Annual Tests

1125 All establishments where approved electrodes are manufactured shall be subject to annual inspection. On these occasions, samples of the approved electrodes shall be subjected to at least the following tests:—

One tensile and three impact specimens in duplicate are to be made from deposited metal as set forth in 1106, 1107 and 1108. One group of specimens is to be prepared using one size of electrode and one using another, neither size being smaller than 4 mm (8 S.W.G.) nor larger than 8 mm ($\frac{5}{10}$ in).

The tensile stress, yield stress and elongation are to be in accordance with 1107 and the impact properties in accordance with 1108 for the approved Grade.

Where an electrode is approved for the welding of higher tensile steel, the tensile stress shall not be less than 47 kg/mm² (30 ton/in²).

For electrodes approved for downhand deep penetration butts and horizontal vertical fillet welds the following tests are to be carried out:—

Two plates of thickness twice the core of the electrode plus 2 mm (0.08 in) are to be butt welded together with one downhand run of welding from each side using a 6 mm (4 S.W.G.) electrode, or the largest size made if less than 6 mm (4 S.W.G.). The plates are not to be less than 100 mm (4 in) wide and of sufficient length to cut out one transverse tensile specimen, two bend test specimens and three Charpy V-notch impact specimens to the dimensions shown in Fig. P 11.7. The notch in the Charpy specimens is to be taken in the centre of the weld metal.

The dimensions of the test pieces and the requirements to be fulfilled are as set forth in the original approval tests in 1117, 1118 and 1119.

At each cut in the test assembly, the joints are to be examined to ensure that complete fusion has taken place. For those electrodes which are approved for normal penetration welding and for deep penetration properties in the downhand position, these tests are to be carried out in addition to the deposited metal tests for normal penetration electrodes.

Upgrading

1126 Upgrading of electrodes will be considered only at the manufacturer's request, preferably at the time of annual testing. Charpy impact tests are to be carried out on specimens taken from butt welded assemblies as required by 1112 (downhand and vertical where applicable). This is in addition to the normal requirements for annual testing.

Additional Tests

1127 If any of the above tests fail, test pieces in duplicate of the same type are to be prepared (if possible using electrodes from the same batch) and are to be satisfactorily tested. (For special requirements for Charpy tests see 1108.)

1128 The Committee may require, in any particular case, such additional tests or requirements as may be necessary.

WIRE-FLUX COMBINATIONS FOR SUBMERGED ARC WELDING

- 1129 The tests are intended for automatic or semiautomatic single electrode submerged arc welding of hull structural steel. The wire-flux combinations are divided into two categories:—
 - (a) For use with the multi-run technique.
 - '(b) For use with the two-run technique; in this case a butt weld is made with one run from each side.

Where a manufacturer states that a particular wire-flux combination is suitable for welding with both techniques, both series of tests are to be carried out.

1130 Wire-flux combinations will be divided into Grades I, 2 and 3, dependent on the results of the Charpy tests. Those which have satisfied the requirements of Grade 2 will also be considered as satisfying Grade 1 requirements and those which have satisfied the requirements of Grade 3 will be considered as complying with Grades 1 and 2 requirements.

The suffix T, M or TM will be added to the Grade mark to indicate two-run technique, multi-run technique, or both techniques respectively. The welding current may be either a.c. or d.c. (electrode positive or negative) according to the recommendation of the manufacturer. If both a.c. and d.c. are recommended, a.c. is to be used for the tests.

Multi-run Technique

1131 When approval for use with multi-run technique is required deposited metal and butt weld tests are to be carried out.

Deposited Metal Tests

1132 Tensile and impact tests are to be made, under controlled conditions, on metal deposited from the wire-flux combination.

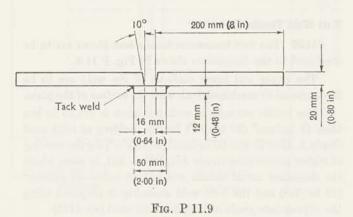
An all-weld-metal test assembly is to be prepared in the downhand position as shown in Figs. P 11.9 and P 11.10, using any grade of hull structural steel.

The bevelling of the plate edges is to be carried out by machining or mechanized gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges.

The direction of deposition of each run is to alternate from each end of the plate and after completion of each run the flux and welding slag is to be removed. Between each run the assembly is to be left in still air until it has cooled to 250° C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is not to be less than the diameter of the wire but not less than 4 mm (0·16 in).

The welding conditions (amperage, voltage and rate of travel) are to be in accordance with the recommendations of the manufacturer and are to conform with normal, good welding practice for multi-run welding.

The welded assembly is to be cut longitudinally at a distance of 30 mm (1 \cdot 20 in) from the edges of the weld and then cut transversely.



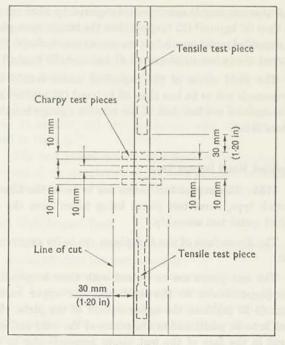


Fig. P 11.10

Deposited Metal Tensile Tests

1133 Two tensile test pieces are to be machined to the dimensions shown in Fig. P 11.2, care being taken that the longitudinal axis coincides with the centre of the weld, and the mid-thickness of the plates.

The tensile test pieces may be subjected to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

Where approval is required for the welding of mild steel of Grade A, D or E, the tensile strength of each test specimen is not to be less than 41 kg/mm² (26 ton/in²) nor more than 57 kg/mm² (36 ton/in²). Where this upper limit is exceeded special consideration will be given to the approval of the wire-flux combination, taking into consideration the other physical properties shown by the test results, and the chemical composition of the weld metal.

The yield stress is not to be less than 31 kg/mm² (19.6 ton/in²) and the elongation not less than 22 per cent on a gauge length of 50 mm (2 in).

Where approval is required for the welding of higher tensile steel of Grades AH, DH or EH, the tensile strength is not to be less than 50 kg/mm² (32 ton/in²) nor more than 68 kg/mm² (43 ton/in²). Where this upper limit is exceeded, special consideration will be given as above.

Alternatively, if the butt weld assembly as required by 1135 is prepared using higher tensile steel of Grade AH, DH or EH, as appropriate, and provided the tensile strengths of

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the transverse tensile specimens as required by 1136 are not less than 50 kg/mm² (32 ton/in²) then the tensile strength of the deposited metal tensile test specimens may be lower than required above but must exceed 47 kg/mm² (30 ton/in²).

The yield stress of the deposited metal tensile test specimens is not to be less than 36 kg/mm² (23 ton/in²) and the elongation not less than 22 per cent on a gauge length of 50 mm (2 in).

Deposited Metal Impact Tests

1134 The impact test pieces are to be of the Charpy V-notch type, three test pieces being taken from the deposited metal test assembly.

The dimensions of the test pieces are to be as given in 1108.

The test pieces are to be cut with their longitudinal axes perpendicular to the weld and the upper surface 5 mm (0·20 in) from the upper surface of the plate. The notch is to be positioned in the centre of the weld and is to be cut in the face of the test pieces perpendicular to the surface of the plate as shown in Fig. P 11.10. The tests are to be carried out on an approved Charpy impact machine.

Where approval is required for the welding of mild steel of Grade A, D or E, for Grade 1 combinations the average impact value of the specimens shall not be less than 3,5 kg m (25 ft lb) at about 20°C. The corresponding value for Grade 2 combinations is 3,5 kg m (25 ft lb) at 0°C and for Grade 3 combinations 4,5 kg m (33 ft lb) at -10°C, or 3,5 kg m (25 ft lb) at -20°C.

The individual values of the Charpy specimens should be reasonably uniform and, to this end, a set of three Charpy specimens which meets the required average but which contains one or more values below 2,4 kg m (17 ft lb) when testing at 20°, 0° or -20°C, or 3,0 kg m (22 ft lb) when testing at -10°C, should be disregarded and a further set of three specimens prepared and tested in its place.

Where approval is required for the welding of higher tensile steel Grade AH, DH or EH, for Grade 1 combinations the average impact value of the specimens shall not be less than 4,0 kg m (29 ft lb) at about 20°C. The corresponding value for Grade 2 combinations is 4,0 kg m (29 ft lb) at 0°C, and for Grade 3 combinations 5,2 kg m (38 ft lb) at -10°C, or 4,0 kg m (29 ft lb) at -20°C.

A set of three Charpy values which meets the required average but which contains one or more values below 2,7 kg m (19 ft lb) when testing at 20°C, 0°C or -20°C or 3,5 kg m (25 ft lb) when testing at -10°C should be disregarded and a further set of three specimens prepared and tested in its place.

The test temperature for Grades 2 and 3 test pieces is to be controlled to within \pm 1 degC of the prescribed temperature and the test procedure laid down in 1108 is to be followed.

Butt Weld Tests

1135 A butt weld assembly as shown in Fig. P 11.11 is to be prepared in the downhand position by welding together two 20 mm (0.80 in) plates not less than 150 mm (6 in) in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size.

For Grades 1 and 2 wire-flux combinations Grade A steel is to be used and for Grade 3 wire-flux combinations any grade of steel may be used.

Where approval is required for the welding of higher tensile steel of Grade AH, DH or EH, it is recommended that the butt weld assembly be prepared using the appropriate grade of higher tensile steel (see 1133).

The plate edges are to be prepared to form a single vee joint, the included angle between the fusion faces being 60° and the root face being 4 mm (0·16 in). The bevelling of the plate edges is to be carried out by machining or mechanized gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges.

The welding is to be carried out by the multi-run technique and the welding conditions are to be the same as those adopted for the deposited metal test assembly.

The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

After being welded the test assembly is not to be subjected to any heat treatment.

It is recommended that the welded assembly be subjected to a radiographic examination to ascertain any defects in the weld prior to testing.

The assembly shall then be cut to form two tensile, two face bend, two root bend and three impact test pieces as shown in Fig. P 11.11.

Butt Weld Tensile Tests

1136 The two transverse tensile test pieces are to be machined to the dimensions shown in Fig. P 11.4.

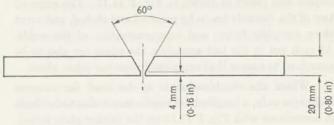
The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

The tensile strength of each test piece is not to be less than 41 kg/mm² (26 ton/in²) for the welding of mild steel Grade A, D or E, and 50 kg/mm² (32 ton/in²) for the welding of higher tensile steel Grade AH, DH or EH, in cases where the deposited metal tensile strength is below 50 kg/mm² (32 ton/in²) and the butt weld assembly is prepared using the appropriate grade of higher tensile steel (see 1133).

Butt Weld Bend Tests

1137 Four transverse bend test specimens, 30 mm (1.20 in) in width, are to be taken from the welded assembly.

The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate



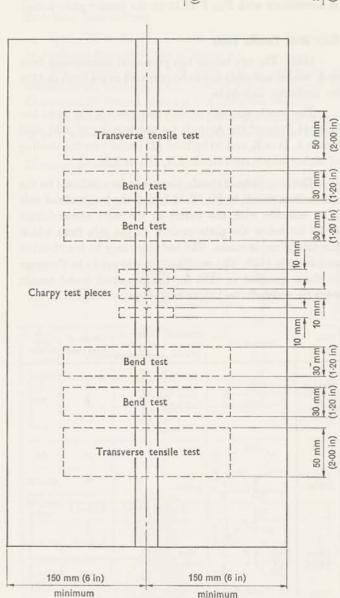


Fig. P 11.11

and the sharp corners of the specimens rounded to a radius not exceeding 2 mm (0.08 in).

The test specimens are to be capable of withstanding, without fracture, being bent through an angle of 120° over a former having a diameter three times the thickness of the specimen.

Two specimens are to be tested with the face of the weld in tension and two specimens with the root of the weld in tension.

The test pieces can be considered as complying with the test if, on completion of the test, no crack or defect at the outer surface of the test specimen can be seen.

Butt Weld Impact Tests

1138 Three Charpy V-notch impact test pieces are to be machined from the test assembly.

The test specimens are to be prepared as shown in Fig. P 11.5, to the dimensions given in 1108. The test specimens are to be taken from the middle of the plate thickness with the notch perpendicular to the surface of the plate.

The average value of the results of the Charpy impact tests is to be in accordance with the requirements for deposited metal given in 1134.

Two-run Technique

1139 Two welded assemblies are to be prepared in accordance with Fig. P 11.12 using the following plate thickness:—

For Grade 1 approval—12 to 15 mm and 20 mm (0.50 to 0.60 in and 0.80 in).

For Grades 2 and 3 approval—20 mm and 35 mm (0.80 in and 1.40 in).

Where approval is required for the welding of higher tensile steel Grade AH, DH or EH, two assemblies are to be prepared using higher tensile steel in addition to the two assemblies using mild steel.

1140 The maximum diameter of wire, grades of steel plate and edge preparation to be used are to be in accordance with Fig. P 11.13. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The bevelling of the plate edges is to be performed by machining or mechanized gas cutting. In the latter case any remaining scale is to be removed from the bevelled edges. The root gap should not exceed 0,7 mm (0.03 in).

Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to 100°C., the temperature being taken in the centre of the weld, on the surface of the seam.

After being welded the test assemblies are not to be subjected to any heat treatment.

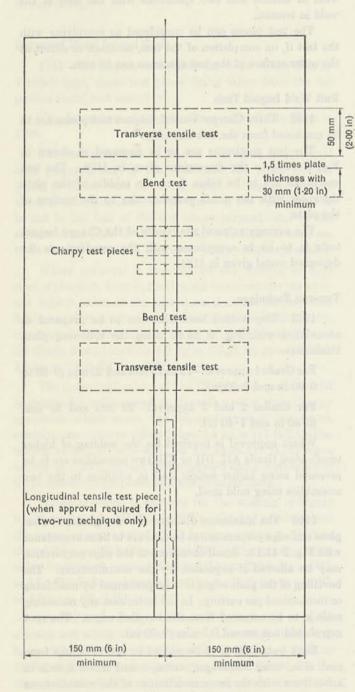


Fig. P 11.12

It is recommended that the welded assemblies be subjected to radiographic examination to ascertain any defects in the weld prior to testing.

The assemblies shall each be cut transversely to form two tensile test pieces, two bend test pieces and three impact test pieces as shown in Fig. P 11.12. The edges of two of the discards are to be polished and etched, and must show complete fusion and interpenetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

Where the combination is to be used for two-run technique only, a longitudinal tensile test is also to be made in accordance with Fig. P 11.12 on the thicker plate tested.

Butt Weld Tensile Tests

1141 The two tensile test pieces cut transversely from each welded assembly are to be prepared as set forth in 1136 for multi-run technique.

The tensile strength of each test piece is not to be less than 41 kg/mm² (26 ton/in²) for the welding of mild steel Grade A, D or E, and 50 kg/mm² (32 ton/in²) for the welding of higher tensile steel Grade AH, DH or EH.

The longitudinal tensile piece is to be machined to the dimensions shown in Fig. P 11.2, and the longitudinal axis is to coincide with the centre of the weld about 7 mm (0·28 in) below the plate surface on the side from which the second run is made. The test piece may be heat treated as set out in 1133. The results of the test are to be the same as those specified in 1133 for the deposited metal tensile tests for multi-run technique test pieces.

Plate thickness	Preparation	Maximum diameter of wire	Grade of wire/flux combination	Grade of mild steel	Grade of higher tensile steel
12mm — 15mm (0•50in — 0•60in)		5mm (0•20in)	1	A	AH
	60° (88	iii d	1	A	АН
20mm (0•80in)	8mm (0.32in)	6mm (0•24in)	2	А	AH or DH
			3	C,D or E	AH, DH orEH
35mm	20° E 131 (1920)	7mm	2	B, Cor D	AH or DH
(1-40in)	7mm (0-28in) (4mm) (0-56in)	(0+28in)	3	C, D or E	AH, DH or EH

Fig. P 11.13

Butt Weld Bend Tests

1142 Two transverse bend tests are to be taken from each welded assembly. The width of the test piece is to be 1,5 times the thickness of the plate with a minimum of $30 \text{ mm} (1 \cdot 20 \text{ in})$ for plates up to $20 \text{ mm} (0 \cdot 80 \text{ in})$ thick, and the test pieces are to be prepared in accordance with 1137.

One specimen from each assembly is to be tested with the side first welded in tension and one with the other side in tension.

The results of the tests and the conditions for acceptance are to be the same as those specified in 1137 for the multi-run technique test pieces.

Butt Weld Impact Tests

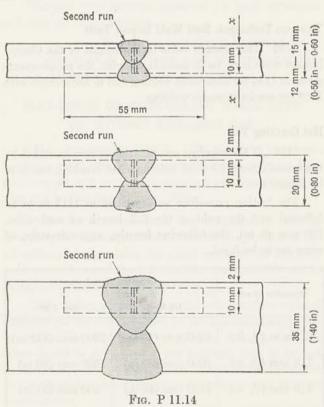
1143 Three Charpy V-notch impact test pieces are to be machined from each welded assembly.

The position of the test piece and of the notch in relation to the welded seam is shown in Fig. P 11.14, and the dimensions of the test piece are to be as given in 1108.

The average value of the results of the Charpy tests is to be in accordance with the requirements given in 1134.

Chemical Analysis

1144 The chemical analysis of the weld metal made by the wire-flux combination is to be supplied by the manufacturer.



The plate material used shall have an analysis which is representative of the grade of steel laid down for the test.

Periodical Inspection of Maker's Works and Annual Tests

1145 All establishments where approved electrodes are manufactured shall be subject to annual inspection. On these occasions, samples of the approved wire-flux combinations shall be subject to at least the following tests:—

MULTI-RUN TECHNIQUE:-

Deposited metal tests—two tensile and three impact tests. Where a combination is approved for the welding of higher tensile steel, the tensile strength shall not be less than 47 kg/mm² (30 ton/in²).

Two-run Technique:-

Transverse specimens taken from a 20 mm. butt weld assembly—two tensile, two bend and three impact tests. Where a combination is approved for the welding of higher tensile steel, the assembly is to be prepared using higher tensile steel.

The specimens are to be prepared and tested in accordance with, and on grades of steel laid down for, first approval.

Additional Tests

1146 If any of the above tests fail, test pieces in duplicate of the same type are to be prepared (if possible using wire-flux combination from the same batches) and are to be satisfactorily tested. For special requirements for additional Charpy tests, see 1108.

1147 The Committee may require, in any particular case, such additional tests or requirements as may be necessary.

WIRE/GAS COMBINATIONS

1148 Paragraphs 1129-1147 apply to the approval of wire/gas combinations, whether for automatic or semi-automatic welding, except as otherwise required by the following Rules.

Where approval is required for both automatic and semiautomatic welding, all-weld-metal and butt weld assemblies are to be made by both methods. The term semi-automatic is used to describe processes in which the weld is made manually by a welder holding a gun through which the wire is continuously fed.

Multi-run Technique. Deposited Metal Assemblies

1149 Two all-weld-metal assemblies as described in 1132 and as shown in Fig. P 11.1 for manual electrodes are

to be prepared, one using 0,8 mm ($_{3\frac{1}{2}}$ in) diameter wire or the smallest size manufactured, and the other using 2,4 mm ($_{3\frac{3}{2}}$ in) diameter wire or the largest size manufactured.

Multi-run Technique. Deposited Metal Impact Tests

1150 The average value of the results of the Charpy impact tests is to be in accordance with the requirements given in 1134 for automatic welding and in accordance with 1108 for semi-automatic welding.

Multi-run Technique. Butt Weld Assemblies

1151 Butt weld assemblies, as shown in Fig. P 11.3 for manual electrodes, are to be prepared for each welding position (downhand, vertical and overhead) for which the combination is recommended by the manufacturer.

Where the combination is to be approved in the downhand position only, an additional test assembly is to be prepared in that position.

In preparing the welded assemblies the first run should be made using $0.8 \text{ mm} \left(\frac{1}{3^{\frac{1}{2}}} \text{ in}\right)$ diameter wire or the smallest size manufactured. The remaining runs should be made by $1.2 \text{ mm} \left(\frac{3}{6^{\frac{1}{4}}} \text{ in}\right)$ diameter wire or larger as recommended by the manufacturer.

Multi-run Technique. Butt Weld Impact Tests

1152 The average value of the results of the Charpy impact tests is to be in accordance with the requirements given in 1134 for automatic welding and in accordance with 1108 for semi-automatic welding.

Two-run Technique Assemblies

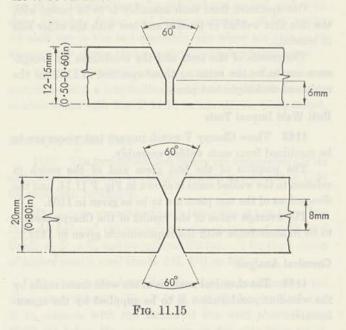
1153 Two welded assemblies are to be prepared for each welding position for which approval is required in accordance with Fig. P 11.12, one using plate thickness 12 mm-15 mm (0·50 in-0·60 in) the other using plate thickness 20 mm (0·80 in). If approval is required for welding of thicknesses greater than 20 mm (0·80 in), one assembly is to be prepared using plate thickness 20 mm (0·80 in), the other using plate of the greatest thickness for which approval is required.

For Grades 1 & 2 wire/gas combinations Grade A steel is to be used, and for Grade 3 wire/gas combinations any grade of steel may be used.

Where approval is required for the welding of higher tensile steel of Grade AH, DH or EH, for Grades 1 and 2 wire/gas combinations Grade AH is to be used, and for Grade 3 wire/gas combinations any grade of higher tensile steel may be used.

The maximum diameter of wire to be used is 1,6 mm ($\frac{1}{16}$ in) or the smallest size manufactured if greater than this. The edge preparations are to be as in Fig. P 11.15.

For assemblies using plate thickness over 20 mm (0.80 in) the edge preparation and wire diameter proposed are to be submitted.



Two-run Technique. Butt Weld Impact Tests

1154 The average value of the results of the Charpy impact tests is to be in accordance with the requirements given in 1134 for automatic welding and in accordance with 1108 for semi-automatic welding.

Hot Cracking Test

1155 If the wire/gas combination is recommended by the manufacturer for fillet welding a hot cracking test is to be carried out.

The testing procedure as described in 1113 is to be followed and for welding the full length of each fillet, 120 mm (5 in), the following lengths, approximately, of wires are to be fused.

N	Length of fused wire		
Diameter of wire	1st fillet	2nd fillet	
0,8 mm (31 in)	4800 mm (190 in)	3600 mm (142 in)	
$1,2 \text{ mm } (\frac{3}{64} \text{ in})$	2000 mm (80 in)	1500 mm (60 in)	
1,6 mm (1 in)	1200 mm (48 in)	900 mm (35 in)	

Annual Tests

1156 Wire/gas combinations approved for automatic welding only.

(a) Multi-run technique—tests as required by 1145. For the preparation of the deposited metal assembly, the wire diameter should be about the centre of the range of diameters manufactured. Two-run technique—tests as required by 1145. For the preparation of the butt weld assembly, the wire diameter should be as recommended by the manufacturer and the thickness of the assembly should be the maximum for which the combination is approved in the two-run technique.

Wire/gas combinations approved for semi-automatic welding only.

(b) Two deposited metal assemblies are to be prepared and tested as required by 1125, one using 0,8 mm ($_{3}^{1}$ ₂ in) diameter wire or the smallest size manufactured, and the other using 2,4 mm ($_{3}^{2}$ ₂ in) diameter wire or the largest size manufactured.

If the combination is approved for semiautomatic welding in the two-run technique an assembly as described in (a) above is to be prepared and tested.

Wire/gas combinations approved for both automatic and semi-automatic welding.

(c) The annual tests should be carried out as described in (b) above using the semi-automatic process for welding the assemblies.

FLUX-CORED OR FLUX-COATED WIRES WITH OR WITHOUT SHIELDING GAS

1157 Paragraphs 1148 to 1156 for wire/gas combinations apply also to the approval of flux-cored or flux-coated wires with or without shielding gas except as otherwise required by the following Rules.

1158 Where more than one diameter of wire is produced, the diameters to be used in the preparation of the all-weld-metal assemblies, the multi-run and two-run butt weld assemblies and the hot cracking test assembly are to be agreed before welding commences.

1159 If flux-cored or flux-coated wires with or without shielding gas are recommended by the manufacturer for use in applications requiring low hydrogen content, then the wires should be submitted to the hydrogen test, as set out in 1114, adapted to suit the process. A suffix H will be added to the Grade number to indicate compliance with the test requirements,

COMBINATIONS FOR USE IN ELECTRO-SLAG AND ELECTRO-GAS WELDING

1160 Paragraphs 1139 to 1147 apply to the approval of combinations for use in electro-slag and electro-gas welding with or without consumable nozzles, except as otherwise required by the following Rules.

1161 Two welded assemblies are to be prepared, one in 20 mm (0.80 in) thick plate and the other in 35 mm (1.40 in) thick plate. The grade of steel to be used for each of these assemblies is to be in accordance with Fig. P 11.13.

The welding conditions and the edge preparation adopted are to be in accordance with the recommendations of the manufacturer.

1162 Each assembly shall be cut to form test pieces as follows:—

Two longitudinal tensile test pieces from the centre of the weld.

Two longitudinal tensile test pieces with their axes on the fusion line.

Two transverse tensile test pieces.

One root bend test piece.

One face bend test piece.

Three Charpy V-notch test pieces with their notches in the centre of the weld.

Three Charpy V-notch test pieces with their notches 2 mm from the fusion line in the weld metal.

Three Charpy V-notch test pieces with their notches 2 mm from the fusion line in the heat affected zone.

Three Charpy V-notch test pieces with their notches in the parent plate away from the weld.

One macrograph of the weld.

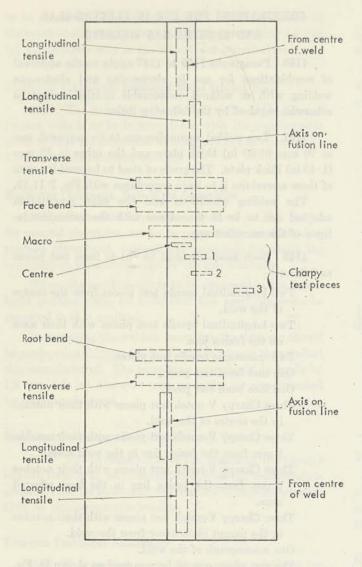
The test pieces are to be arranged as shown in Fig. P 11.16.

Additional Charpy Impact Tests

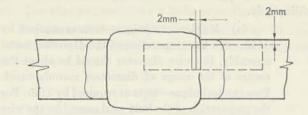
1163 Where approval is required for the welding of higher tensile steel of Grade AH, DH or EH, approval is given either for use only with aluminium treated fine grain steel or for use with aluminium and niobium treated steels. For the latter approval the butt assembly should be prepared using niobium treated steel.

Annual Tests

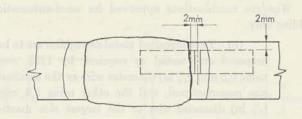
1164 A 20 mm (0·80 in) thick butt weld assembly is to be prepared from which two tensile, two bend and three Charpy V-notch specimens are to be machined and tested. The impact specimens are to have their notches at the centre of the plate thickness vertical to the plate surfaces.



(1) In the weld metal 2 mm from the fusion line.



(2) In heat affected zone 2 mm from the fusion line.



(3) In workpiece remote from weld.

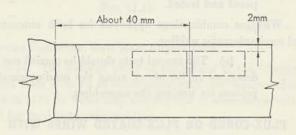


Fig. P 11:16

COMBINATIONS FOR USE IN ONE-SIDE WELDING PROCESSES

1165 The tests and test requirements as laid down in previous paragraphs for the two-run technique for wire/flux combinations, wire/gas combinations and flux-coated or flux-cored wires, as appropriate, are to be used so far as is applicable.

1166 Two butt weld assemblies are to be prepared one in 20 mm (0.80 in) plate and one in 35 mm (1.40 in) plate (assuming no thickness limitation is to be applied). The edge preparation and welding conditions are to be in accordance with the recommendations of the manufacturer.

Test pieces (including the longitudinal tensile test piece) are to be machined from these in accordance with Fig. P 11.12. The Charpy test pieces should be arranged as follows and as shown in Fig. P 11.17.

20 mm (0.80 in) Assembly

1. A set of three Charpy impact test pieces with their notches in the centreline of the weld taken at 20 mm (0.80 in) from the plate surface at the root of the weld.

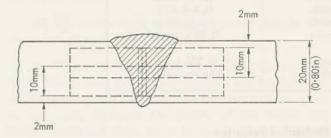
2. A set of three Charpy impact test pieces with their notches in the centreline of the weld taken at 2 mm from the plate surface at the face of the weld.

35 mm (1.40 in) Assembly

1 and 2 as above for 20 mm (0.80 in) assembly.

3. A set of three Charpy impact test pieces with their notches in the centreline of the weld taken at the middle of the plate thickness.

One macrograph should be taken from each assembly.



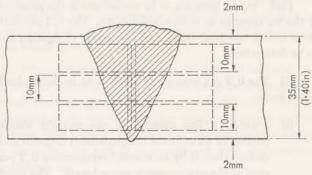


Fig. P 11.17

1167 Annual testing is to be carried out in accordance with 1145 for the two-run technique. The three impact test pieces are to be taken with their notches in the centreline of the weld, 2 mm from the plate surface at the root of the weld.

Section 12

ALUMINIUM ALLOY PLATES, BARS AND SECTIONS

Scope

1201 Aluminium alloy plates, bars and sections intended for use in hull construction are to be manufactured and tested in accordance with the requirements of this Section. These requirements do not apply to plates less than 4.5 mm thick (0.18 in) or to angles and other sections less than $40 \times 40 \times 4.5 \text{ mm}$ $(1.5 \times 1.5 \times 0.18 \text{ in})$. Where thin material of this type is used, the mechanical properties and chemical composition are to be in accordance with a recognized national specification for an aluminium alloy suitable for marine use.

Alternatively, materials complying with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

Manufacture

1202 Aluminium alloys are to be manufactured at works approved by the Committee and a list of approved manufacturers is given in the appendices at the end of Chapter Q.

The alloys may be cast in either ingot moulds or by an accepted continuous casting process.

Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by extrusion, rolling or by drawing.

Chemical Composition

1203 (a) Samples for chemical analysis are to be taken representative of each cast or by an equivalent procedure where a continuous melting process is employed.

The chemical composition of these samples is to comply with the requirements of Table P 12.1.

(b) Where it is proposed to use alloys not specified in Table P 12.1 details of chemical composition, heat treatment and mechanical properties are to be submitted for approval.

Heat Treatment

1204 Grade AL 1 alloys may be supplied in either the "as manufactured" or "annealed" conditions provided that the mechanical properties comply with the values given in Table P 12.3. Grade AL 2 alloys are to be supplied in the solution treated and precipitation hardened condition.

Test Material

1205 (a) Material of the same section and thickness produced in the same way and of the same chemical composition, is to be presented for testing in batches of not more than 4000 kg (4 tons).

If the material is supplied in the heat treated condition, then each batch is to be subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch type furnace.

(b) At least one tensile test piece is to be taken from material representative of each batch. These are to be cut with their length transverse to the principal direction of rolling for plates over 300 mm (12 in) in width. For narrow plates and for sections and bars the tests are to be cut in the longitudinal direction.

TABLE P 12.1

Grade	AL 1	AL 2
Copper Magnesium Silicon Iron Manganese Zinc	0,10% max, 3,5-5,6% 0,5% max, 0,5% max, 1,0% max, 0,2% max.	0,10% max. 0,4-1,4% 0,6-1,6% 0,5% max. 0,2-1,0% 0,2% max.
Chromium Titanium and other grain	0,35% max.	0,35% max.
refining elements Aluminium	0,2% max. The remainder	0,2% max. The remainder

- (c) Material for the preparation of these tests is not to be cut until heat treatment (where applicable) has been completed nor until it has been identified by the Surveyor or an authorized deputy.
- (d) Any straightening of test pieces which may be required is to be done cold and the test pieces shall not receive further heat treatment or mechanical working before being tested except by machining to shape.
- (e) For routine purposes, tensile test pieces from plates and sections are to be of square or rectangular cross-section. These are to be machined to a minimum width of 12,0 mm (0.47 in) and are to be of the full thickness of the material with the wrought surfaces retained. Machined test pieces of circular cross-section may, however, be used as an alternative provided the diameter is not less than 10 mm (0.399 in). The dimensions are to be as shown in Table P 12.2. The ends may be machined in a form suitable for the grips of the testing machine provided there is an adequate radius between the test length and the enlarged ends.

Round bars may be tested in full section or test pieces may be machined in accordance with the dimensions given in Table P 12.2.

Mechanical Properties

1206 (a) All tests are to be carried out in the presence of the Surveyor or an authorized deputy. The 0,2 per cent proof stress, tensile strength and percentage elongation are to be determined.

- (b) The 0,2 per cent proof stress is to be determined either by:—
 - (i) drawing a line parallel to the straight elastic portion of an accurate load/extension diagram and distant from it by an amount representing 0,2 per cent of the extensometer gauge length. The point or intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 per cent proof stress can be calculated:
- or (ii) subjecting the test piece to the specified minimum proof stress and removing the load when the test piece shall not have acquired a permanent elongation, measured by an extensometer, greater than 0,2 per cent of the extensometer gauge length.

TABLE P 12.2

Cross Section	Gauge Length	Minimum Parallel Length
Square or Rectangular	5,65√S _o or 50 mm (2 in)	$7,15\sqrt{S_0}$ $50+1,5\sqrt{S_0}$ mm $(2+1,5\sqrt{S_0}$ in
Circular	5d or 50 mm (2 in)	5,5d $50 + \frac{d}{2} \text{ mm } (2 + \frac{d}{2} \text{ in})$

So = Cross-sectional area of test piece,

d = diameter of test piece.

- (c) The rate of increase of stress in the upper half of the elastic range and until the proof load has been reached is not to be greater than 1 kg/mm²/second (0.6 ton/in²/second.) After reaching the proof load the rate of straining may be increased to a maximum of 40 per cent of the original gauge length per minute for the determination of the tensile strength.
- (d) The results of all tensile tests are to comply with the values given in Table P 12.3.
- (e) Where the tensile test piece representative of a batch fails to meet the test requirements and the Surveyor considers the results obtained from the fractured test piece do not fairly represent the quality of the batch, two further tensile test pieces are to be taken. These additional tests are to be prepared from material adjacent to the original test. In such cases the quality of the batch is to be judged by the result of the re-tests and not by the original test which failed.

When a test covering a batch of material fails and one or both of the re-tests also fail then the item or piece from which the tests were prepared is to be rejected. At the discretion of the Surveyor further tensile test pieces may be selected from at least two pieces of the remaining material in the batch for testing in accordance with the specified requirements.

Where material is tested in the heat treated condition and fails test, the whole of the material represented by the test piece may be re-heat treated and re-submitted for test provided that the material is not solution heat treated more than three times, i.e., original and two re-treatments.

Inspection

- 1207 (a) The manufacturer shall afford the Surveyors all necessary facilities and access to all relevant parts of the works to enable them to verify that the approved method of manufacture is adhered to, for the selection of the test material, the witnessing of tests and the examination of material as required by the Rules.
- (b) Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.
- (c) Materials are to be free from defects of such a nature as would be harmful in service. The surface finish is to be in accordance with good practice and surfaces are not to be treated in any way that may invalidate the surface examination.

Where there is visible evidence to doubt the soundness of any material, such as flaws in test pieces or suspicious surface marks, the Surveyor may require the manufacturer to prove the material by a suitable method.

(d) In the event of any material proving unsatisfactory during subsequent working, machining or fabricating, due to faults in manufacture, such material is to be rejected notwithstanding any previous certification and such tests of further material from the same cast may be made as the Surveyor may consider desirable.

Repair of defective material

1208 Slight surface imperfections may be removed by mechanical means, provided the prior agreement of the

TABLE P 12.3

Grade	AL 1	AL 2
0,2% Proof Stress kg/mm ² minimum Tensile Strength kg/mm ² ,, Elongation (on 5,65 $\sqrt{S_0}$) per cent minimum	12,5 27,0 11	20,0 27,0 8
(on 50 mm) per cent ,,	12	8

or in British Units:-

Grade	AL 1	AL 2
0.2% Proof Stress ton/in ² minimum Tensile Strength ton/in ² ,, Elongation (on $5.65\sqrt{S_0}$) per cent minimum	7·9 17·1 11	12·7 17·1 8
(on 2 in) per cent ,,	12	8

Surveyor is obtained, the work is carried out to his satisfaction and the final dimensions are acceptable.

The repair of defects by welding is not permitted.

Identification

- 1209 (a) The manufacturer is to adopt a system of identification which will enable all finished material to be traced through all stages to the original cast and the Surveyors are to be given full facilities for so tracing the material when required.
- (b) Before any item is finally accepted, it is to be clearly marked by the manufacturer in at least one place with the following particulars:—
 - (1) The Society's brand R
 - (2) The manufacturer's name or trade mark,
 - (3) Identification mark for the grade of alloy,
 - (4) Identification mark which will enable the full history of the item to be traced,
 - (5) Purchaser's identification mark if required by the purchaser.

Hard stamping is to be used except when this may be detrimental to the material, when stencilling, painting or electric etching may be used.

Where a number of identical items are securely fastened together in bundles, subject to the agreement of the Surveyor, the manufacturer may brand only the top piece of each bundle, or alternatively, a durable label giving the required particulars may be attached to each bundle.

(c) When material is marked with the Society's brand prior to completion of mechanical tests and is subsequently rejected, the Surveyor is to ensure that all these marks are effectively defaced.

Documentation

- 1210 (a) The Surveyor shall be supplied with at least two copies of the mill sheets or shipping statements of all accepted material and these documents should be separate for each grade of aluminium alloy. The documents should contain, in addition to the description, dimensions, etc., of the material, the following particulars:—
 - (i) Purchaser's name.
 - (ii) Manufacturer's name.
 - (iii) Identification mark which will enable the full history of the item to be traced.
 - (iv) Identification of grade of alloy.

- (v) Chemical composition.
- (vi) Details of heat treatment (where applicable).
- (vii) Order or ship number for which intended.
- (b) Before the mill sheets or shipping statements are signed by the Surveyor, the manufacturer is required to furnish him with a certificate stating that the material has been made in accordance with the requirements of this Section and that it has been subjected to, and has withstood satisfactorily, the required tests in the presence of the Surveyor or his authorized deputy. The following form of certificate will be accepted if stamped or printed on each mill sheet with the name of the works and initialled for the manufacturers by an authorized official:—

(c) Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied to the Surveyor at the fabricating plant stating the name of the manufacturer, the cast number, identification and the chemical composition. The works at which the alloy was produced must be approved by the Committee.

Section 13

ALUMINIUM ALLOY RIVETS

 1301 Aluminium alloy rivets intended for use in hull construction are to be manufactured and tested in accordance with P 12 except as undernoted.

Chemical Composition

1302 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table P 13.I.

Bar Material

- 1303 (a) All bar material intended for the manufacture of rivets is to be tested.
- (b) Material of the same diameter, produced in the same way and of the same chemical composition, shall be grouped into batches not exceeding 250 kg (0.25 ton) in

TABLE P 13.1

Grade	AL 3	AL 4	
Copper	0,10% max.	0,10% max.	
Magnesium	3,0-3,9%		
Silicon	0,5% max.	0,4-1,4% 0,6-1,6%	
Iron	0,5% max.	0,5% max.	
Manganese	0,6% max.	0,2-1,0%	
Zine	0,2% max.	0,2% max.	
Chromium	0,35% max.	0,35% max.	
Titanium and other grain		, , , ,	
refining elements	0,2% max.	0,2% max.	
Aluminium	The remainder	The remainder	

weight. At least one test sample is to be taken from a coil or length from each batch and is to be suitably heat treated prior to the preparation of mechanical test pieces. Test samples from Grade AL 3 alloy are to be annealed and from Grade AL 4 alloy solution treated.

- (c) One tensile and one dump test piece are to be prepared from each test sample.
- (d) The results of all tensile tests are to comply with the values given in Table P 13.2.
- (e) Test pieces of a length and diameter equal to the full diameter of the bars shall, when cold, withstand being compressed without cracking until the diameter is increased to 1,6 times the original diameter.

Manufactured Rivets

- 1304 (a) Rivets manufactured of the grade AL 3 alloy are to be supplied in the annealed condition while rivets of grade AL 4 alloy are to be supplied in the solution treated condition.
- (b) From each consignment of manufactured rivets, at least three samples are to be selected for the dump test as described in 1303 (e).

Section 14

WELDING OF ALUMINIUM ALLOYS

- 1401 For general requirements where welding is employed, see D 3221.
- 1402 Grade AL 1 aluminium alloys are to be welded by the metal inert gas or tungsten inert gas processes. Where it is proposed to use other welding processes, details are to be submitted for approval.

Grade AL 2 aluminium alloys are not generally suitable for welded construction.

1403 The chemical composition of filler wire used in welding is to conform to the following requirements:—

Copper				0,10	pe:	r cen	t max
Magnesium				4,5	- 5,	5 pe	er cent
Silicon		***		0,6	per	cent	max.
Iron				0,5	,,	**	**
Manganese				1,0			,,
Zinc			200				2.2
Chromium				0,4			**
Titanium	and	other					
refining	elem	ents		0,2	,,	,,	,,
Aluminium	ı			The			

TABLE P 13.2

		Tensile Strength Minimum kg/mm ²	Elonga	tion	British Units	
Grade	0,2% Proof Stress Minimum kg/mm ²		On 5,65 $\sqrt{S_0}$ Minimum	On 50 mm (2 in) Minimum %	0·2 % Proof Stress Minimum ton/in ²	Tensile Strength Minimum ton/in ²
AL 3	9	22	18	16	5.8	14.0
AL 4	12	19	16	14	7.8	12.4

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Chapter Q

MATERIALS FOR BOILER, PRESSURE VESSEL AND MACHINERY CONSTRUCTION

Note. For list of steel manufacturers see Appendix following this Chapter

General

Materials used in the construction of boilers, pressure vessels and machinery are to be manufactured and tested in accordance with the requirements contained in the following sections of this Chapter:—

- Section 1. General requirements for Steel Plates, Sections, Bars, Castings, Forgings, Tubes and Pipes,
 - ,, 2. Dimensions of test pieces and methods of test.
 - ,, 3. Rolled steel plates,
 - , 4. Rolled steel sections and bars,
 - 5. Steel castings,
 - ,, 6. Steel forgings,
 - , 7. Steel tubes and pipes,
 - " 8. Cast iron crank shafts,
 - " 9. Copper alloy propellers and propeller blades.

Section 1

GENERAL REQUIREMENTS

Scope

101 (a) General requirements for Steel Plates, Sections, Bars, Castings, Forgings, Tubes and Pipes intended for use in the construction of boilers, pressure vessels and machinery.

These items are to be manufactured and tested in accordance with the requirements given in this Section and Q 2, together with the specific requirements contained in the relevant Sections Q 3 to Q 7.

Approval of Works

(b) Steel is to be manufactured at works approved by the Committee. A list of approved manufacturers is given in the Appendix at the end of this Chapter.

Orders for Materials

(c) The order is to specify the required grade and condition of the material and the purpose for which it is intended.

Where material is required to have guaranteed properties at low or high temperature, the reference temperature for testing purposes is to be stated. This reference temperature is generally to be selected from those tabulated in the Sections giving specific requirements.

Manufacture

102 (a) Steel is to be manufactured by the openhearth, electric furnace or oxygen processes or by other processes approved by the Committee. An oxygen process is defined as a process in which molten iron contained in a basic lined converter is refined by directing a jet of high purity gaseous oxygen on to the surface of the hot metal.

The steel-making practice is to be such as to minimize the included non-metallic content of the finished steel. Acceptable deoxidation practices are given under the specific requirements in subsequent Sections of this Chapter.

- (b) The steel is to be cast in metal ingot moulds or by an approved continuous casting process. The size of the ingot or of the continuous cast billet or slab is to be proportional to the dimensions of the final product in order that the amount of mechanical work will be adequate to ensure a satisfactory steel structure in the finished product. Provision is also to be made for sufficient discard to be taken from the top and bottom of each ingot to ensure soundness in the portion used for further processing. Periodically, and at the Surveyor's discretion, sulphur prints or other suitable proving tests may be required to demonstrate that this has been fulfilled.
- (c) For certain important components it is required that the method of manufacture, or processing, be specially approved. When this condition applies, it is stated in the relevant specific requirements, and all necessary details are to be submitted for approval before production commences.

Chemical Analysis

103 The chemical composition is to be determined by the makers in an adequately equipped and competently staffed laboratory on samples taken from each ladle of each cast. The maker's analysis will be accepted but may be subject to occasional checks if required by the Surveyors.

Heat Treatment

104 All materials are to be supplied in the condition specified, or permitted, in the relevant Sections of this Chapter. Acceptable heat treatment processes and temperatures are detailed in the specific requirements. Where it is proposed to use a controlled rolling procedure, full details are to be submitted for approval.

Items normally supplied in the "as rolled" or "as drawn" condition may be subjected to a heat treatment proposed by the manufacturer for the purpose of obtaining the specified test results. Where material is supplied in the "as rolled" condition for subsequent re-working, e.g., plates for hot forming, billets for re-forging, etc., the manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or to make the material in a safe condition for transit. The proposed heat treatment is to be agreed by the Surveyor.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for temperature control and are fitted with pyrometers which measure the temperature of the furnace charge. The furnace dimensions must permit the whole item being uniformly heated to the necessary temperature. In the case of very large structures which require heat treatment, alternative methods will be specially considered.

Test Material

105 (a) Sufficient test material is to be provided for the preparation of the tests detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

The test material is to be representative of the item, piece or batch. Cold straightening of test material may be carried out when permitted in the specific requirements, but otherwise the material is not to be re-worked or mechanically treated in any way which may influence the properties. Generally, test material is not to be removed from the item or piece until all heat treatment has been completed, except where an alternative procedure has been specially approved or where provision is made in the specific requirements for a simulated stress relieving, or blank carburizing heat treatment.

All test material is to be selected and identified by the Surveyor or an authorized deputy. These identification marks are to be maintained during the preparation of the test pieces. Dimensions of test pieces are to be in accordance with Q 2.

Definitions

(b) Piece or rolled length in respect of plates, bars and sections, is the rolled product from a single slab, bloom or ingot if this is rolled directly into plates, bars or sections.

Item is a single plate, bar, section or component as delivered.

Test material or test block is the material from which the test piece is prepared.

Test piece is the portion of the test material or test block on which the actual test is carried out.

Mechanical Tests

106 (a) All prescribed mechanical tests are to be carried out by the manufacturer before the material is despatched and unless otherwise agreed they are to be witnessed by the Surveyor.

Test methods are to be in accordance with the procedures detailed in Q 2 and the results of all tests are to comply with the specific requirements given in subsequent sections.

The tests are to be carried out by competent personnel on machines of approved types. The machines are to be maintained in a satisfactory and accurate condition and are to be re-calibrated at approximately annual intervals. This calibration is to be carried out by a nationally recognized authority or other organization of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

Re-tests

(b) Where either the tensile test or the bend test, or both, fail and the Surveyor considers the fractured test piece or test pieces, or the results obtained therefrom, do not fairly represent the quality of the item or batch, two further test pieces of the same type are to be taken for each original test that failed. These additional tests are to be prepared from material adjacent to the original tests. In such cases the quality of the item or batch is to be judged by the result of the re-tests and not by the original test or tests which failed.

When a test covering a batch of material fails and one, or both, of the re-tests fail then the item or piece from which the tests were prepared is to be rejected. At the discretion of the Surveyor further pieces of the same type may be selected from the remaining material in the batch for testing in accordance with the specified requirements.

In the event of failure to meet impact test requirements, additional tests will only be permitted provided the average result was not less than 85 per cent of the required value. These additional tests are to consist of either three Charpy U- or V-notch test pieces or one Izod test piece, as appropriate, cut from material adjacent to the original tests. The results are to be added to the original results and the material is acceptable if the new average value complies with the specified minimum average value.

Re-heat Treatment

(c) At the option of the manufacturer, when material which is intended to be supplied in the "as rolled" or "as drawn" condition fails test, it may be heat treated and re-submitted for test. The heat treatment may be either normalizing, normalizing and tempering, or as otherwise specially agreed.

When material is tested in the heat treated condition and fails test, it may be tempered or re-tempered and resubmitted for test. It may also be re-heated for normalizing or quenching, provided it is not heated above the upper critical temperature more than three times, i.e., original and two re-treatments.

Alternatively, material which has failed test may be re-submitted as another grade.

Inspection

- 107 (a) The manufacturers shall afford the Surveyors all necessary facilities and access to all relevant parts of the works to enable them to verify that the approved process is adhered to, for the selection of test material, the witnessing of tests and the examination of material as required by the Rules.
- (b) Surface inspection, verification of dimensions and, where appropriate, non-destructive examination are the responsibility of the manufacturer and are to be carried out on all material prior to despatch.

Witnessing of these tests by the Surveyor will be at his discretion except where this is included in the specific requirements or where specially requested by the purchaser.

Materials are to be free from segregations, flaws and laminations of such a nature as would be harmful in service. The surface finish is to be in accordance with good practice and surfaces are not to be hammered, peened or treated in any way that may invalidate the surface examination.

Slight surface imperfections may be removed by mechanical means, provided that after such treatment the dimensions are acceptable and the rectification has been completed to the satisfaction of the Surveyor.

When there is visible evidence to doubt the soundness of any material or component, such as flaws in test pieces or suspicious surface marks, the manufacturer is expected to prove the material by any suitable method. In the event of any material proving unsatisfactory during subsequent working, machining or fabricating, such material is to be rejected notwithstanding any previous certification.

Non-destructive Testing

(c) The techniques employed are to be in accordance with recognized good practice, including any necessary surface preparation and are to be carried out by competent personnel using reliable and efficiently maintained equipment. The term "magnetic particle examination" is intended to imply inspection for surface flaws using suitable magnetic methods, but when this is not practicable a suitable dye penetrant method may be used instead.

Repair of Defective Material

108 The repair of defects by welding is not acceptable unless the agreement of the Surveyor is obtained before the work is commenced. Repair by welding cannot be considered unless it is permitted by the specific requirements of the relevant Section in this Chapter. When a repair has been agreed it is necessary in all cases to prove by suitable methods of inspection that the defects have been completely removed before welding is commenced. Welding procedures, including pre-heating, post-weld heat treatment and inspection are to be to the complete satisfaction of the Surveyor. In all cases, the area is to be magnetic particle tested on completion of welding, heat treatment and surface grinding.

Identification of Material

- 109 (a) The manufacturer is to adopt a system of identification which will enable all finished material to be traced to the original cast and the Surveyors are to be given full facilities for so tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new mark has been made. Failure to comply with this condition will render the item liable to rejection.
- (b) Before any item is finally accepted it is to be clearly marked by the manufacturer in at least one place. The following particulars are to be shown:—

Plates, Bars and Sections

- 1. The Society's brand R,
- 2. The manufacturer's name or trade mark,
- 3. Identification mark for the grade of steel,
- Identification mark which will enable the full history of the item to be traced,
- Purchaser's identification mark if required by the purchaser.

Castings, Forgings, Tubes and Pipes

- "L.R." or "Lloyds" and the abbreviated name of the Society's local office,
- Identification mark which will enable the full history of the item to be traced,
- 3. Date of final inspection,
- Personal stamp of Surveyor responsible for the final inspection.

Hard stamping is to be used except when this may be detrimental to the material, when stencilling, painting or electric etching may be used. Paints used for identifying alloy steels are to be free from lead, copper, zinc or tin.

Where a number of identical items are securely fastened together in bundles, subject to the agreement of the Surveyor the manufacturer may brand only the top piece of each bundle, or alternatively, a durable label giving the required particulars may be attached to each bundle.

(c) When material is marked with the Society's brand R, "L.R.," "Lloyds" or the personal stamp of the Surveyor prior to completion of mechanical tests and is subsequently rejected, the Surveyor is to ensure that all

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these marks are effectively defaced.

a written statement giving the steelmaking process, cast number, cast analysis, mechanical test results and general details of heat treatment used for each item together with full particulars of the purchaser, order number and description.

When steel is not produced at the works at which it is rolled or forged, a certificate is to be supplied to the Surveyor at the rolling mill, forge or tube mill stating the process by which the steel was manufactured, the name of the steelmaker, the cast number, identification and ladle analysis. The works at which the steel was produced must be approved by the Committee.

Section 2

DIMENSIONS OF TEST PIECES AND METHODS OF TEST

Tensile Test Pieces

201 (a) Proportional test pieces for tensile tests with a gauge length of $5,65\sqrt{\text{So}}$, where So is the cross-sectional area of the test length, have been adopted as the standard form of test piece and in subsequent Sections of this Chapter, the minimum percentage elongation values are given for

test pieces of these proportions. For reference purposes the test piece is to be machined to a diameter of 14 mm (0.564 in) with a gauge length of 70 mm (2.80 in). The minimum length of the parallel test length is to be 80 mm (3.15 in) and the ends may be machined in a form suitable for the grips of the testing machine provided there is an adequate radius between the test length and the enlarged ends.

(b) For routine testing purposes round machined test pieces with other diameters and gauge lengths may be used, subject to any requirements for minimum diameter or cross-sectional area given in subsequent Sections. Any of the test pieces detailed below may also be used for routine testing purposes. In all cases where the gauge length used is other than $5,65\sqrt{\text{So}}$ the equivalent percentage elongation is to be calculated using the formulæ or Tables given in 202.

Square or Rectangular Non-Proportional Tensile Test Pieces

(c) These are to be machined to a minimum width of 25 mm (1 in) and are to be the full thickness of the material with the rolled surfaces retained. The gauge length is to be 200 mm (8 in) and the minimum length of the parallel section is to be 225 mm (9 in). For rectangular sections the ratio of the sides is not to exceed 4:1. The ends may be machined to a greater width to suit the grips of the testing machine, provided there is an adequate radius between the test length and enlarged ends.

Full-Section Tensile Test Pieces

(d) Test samples from bars and other small rolled sections may be tested in full section. The cross-sectional area is to be calculated either from accurate measurement of the average dimensions or by determining the weight of a known length.

Tensile Pieces from Tubes and Pipes

(e) Samples from tubes and pipes may be tested in full section as above, provided the ends are plugged and the length of the test piece between the grips is at least 50 mm (2 in) greater than the gauge length.

Alternatively, test pieces may be prepared from strips cut longitudinally from the tubes or pipes. These test pieces are to be machined to a minimum width of 12 mm (0.5 in) but the ends may be machined to a greater width to suit the grips of the machine, provided there is an adequate radius between the test length and the enlarged ends. The central test length is not to be flattened but the enlarged ends may be flattened for gripping in the testing machine. The gauge length is to be 50 mm (2 in) and the minimum length of the parallel portion is to be 60 mm (2 · 4 in).

The cross-sectional area of this type of test piece having parallel edges is to be calculated as follows:—

So =	ab
where So =	cross-sectional area,
a =	average radial thickness,
b =	average width.

For thick walled pipes, the test material may be cut in either a longitudinal or circumferential direction and machined round test pieces prepared.

Equivalent Elongation

202 When a gauge length other than 5,65√So is used, the equivalent percentage elongation value is to be calculated using the following formula:—

$$E = \frac{n}{2} \left[\frac{\text{Lo}}{\sqrt{\text{So}}} \right]^{0.40}$$

where n =actual measured percentage elongation of test piece,

So = actual cross-sectional area of test piece,

Lo = actual gauge length of test piece,

E = equivalent percentage elongation for a test piece with a gauge length of $5,65\sqrt{\text{So.}}$

Alternatively, where a number of test pieces of similar material and dimensions are involved the actual percentage elongation values may be recorded, provided the equivalent specified minimum elongation value appropriate for the test piece dimensions is calculated from the above formula and is recorded on the test sheet.

For proportional test pieces having a gauge length other than $5,65\sqrt{\text{So}}$ the equivalent elongation may be calculated using the following factors:—

Actual gauge	Factor for equivalent
length	elongation on 5,65 VSo
4√So	×0,870
8,16√So	×1,158
11,3√So	×1,317
4d	×0,916
8d	×1,207

For non-proportional test pieces with gauge lengths of 50 mm (2 in) and 200 mm (8 in) the equivalent elongation may be determined from Tables Q 2.1 and Q 2.2.

The above conversions are only reliable for carbon and carbon-manganese steels with a tensile strength not exceeding 70 kg/mm² (44 ton/in²) in the hot rolled, annealed, normalized or normalized and tempered conditions.

For alloy steels in the oil hardened and tempered condition, the following conversion may be used for proportional test pieces with a gauge length of $4\sqrt{So}$.

Actual percentage	Equivalent elongation
elongation on $4\sqrt{So}$	on $5,65\sqrt{So}$
22	17
20	15
18	13
17	12
16	12
15	11
14	10
12	8
10	7
8	5

For the following materials, the acceptance of any proposed conversion factor is to be at the discretion of the Surveyor:—

- (i) Carbon and carbon-manganese steels with a tensile strength exceeding 70 kg/mm² (44 ton/in²),
- (ii) Alloy steels in the normalized or normalized and tempered condition,
- (iii) Cold worked steels,
- (iv) Austenitic steels,
- (v) Non-ferrous alloys.

Discarding of Tensile Test Pieces

203 Where the specified minimum percentage elongation is not obtained, and the distance between the fracture and nearer gauge mark is less than a third of the original gauge length, the test piece is to be discarded. A further test piece is to be prepared and the quality of the material is to be judged entirely on the results obtained from this additional test.

Tensile Tests at Ambient Temperature

- 204 (a) The yield phenomena is not exhibited by all the materials specified in subsequent Sections of this Chapter but, for simplification, reference is only made to yield stress. Where no distinct yield is observed this is to be interpreted as either the 0,2 per cent proof stress or the 0,5 per cent proof stress under load.
 - (b) The yield stress is to be calculated from either:— Beam Machines. The load immediately prior to a distinct drop in the testing machine lever, Indicating Machines. The load immediately prior to a fall back in the movement of the pointer or the load at a marked hesitation of the pointer.
- (c) The 0,2 per cent proof stress is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and distant from it by an amount representing 0,2 per cent of the extensometer gauge

TABLE Q 2.1 Equivalent elongation on 5,65 $\sqrt{\text{So}}$ for test pieces with gauge lengths of 50 mm

Actual per cent. elong. on 50 mm gauge	HEE IS	Corre	esponding p	er cent. elo	ngation on	5,65√ So g	auge length	if cross-sec	ctional area	in mm² is:	The same	
gauge length	50	100	150	200	300	400	500	600	700	800	900	1000
18	20	17	16	15	14	13	12	12	12	11	11	11
19	21	18	17	16	15	14	13	13	12	12	12	11
20	22	19	18	17	15	14	14	13	13	13	12	12
21	23	20	19	18	16	15	15	14	14	13	13	13
22	24	21	20	18	17	16	15	15	14	14	14	13
23	25	22	20	19	18	16	16	15	15	15	14	14
24	26	23	- 21	20	18	17	17	16	16	15	15	15
25	27	24	22	21	19	18	17	17	16	16	15	15
26	28	25	23	22	20	19	18	17	17	16	16	16
27	29	26	24	23	21	20	19	18	18	17	17	16
28	31	27	25	23	22	20	19	19	18	18	17	17
29	32	28	26	24	22	21	20	19	19	18	18	18
30	33	29	27	25	23	22	21	20	19	19	19	18
31	34	30	27	26	24	23	21	21	20	20	19	19
32	35	31	28	27	25	23	22	21	21	20	20	19
33	36	32	29	28	25	24	23	22	21	21	20	20
34	37	33	30	28	26	25	24	23	22	22	21	21
35	38	33	31	29	27	25	24	23	23	22	22	21
36	39	34	32	30	28	26	25	24	23	23	22	22
37	40	35	33	31	28	27 .	26	25	24	23	23	22
38	42	36	34	32	29	28	26	25	25	24	23	23
39	43	37	35	33	30	28	27	26	25	25	24	24
40	44	38	35	33	31	29	28	27	26	25	25	24
41	45	39	36	34	32	30	28	27	27	26	25	25
42	46	40	37	35	32	30	29	28	27	27	26	25
43	47	41	. 38	36	33	31	30	29	28	27	27	26
44	48	42	39	37	34	32	30	29	28	28	27	27
45	49	43	40	38	35	33	31	30	29	28	28	27
46	50	44	41	38	35	33	32	31	. 30	29	28	28
47	51	45	. 42	39	36	34	33	31	30	30	29	28

or in British units:-

TABLE Q 2.1 Equivalent elongation on $5.65\sqrt{\mathrm{So}}$ for test pieces with gauge lengths of 2 in

Act	ual per cent. ng. on 2 in uge length		Correspond	ing per cent	t. elongation	n on 5.65	So gauge le	ength if cro	ss-sectional	area in incl	nes² is:—	
ga	uge length	0.05	0.10	0.20	0.30	0 · 40	0.50	0.60	0.70	0.80	0.90	1.0
	18	22	19	16	15	14	14	13	13	12	12	12
	19	23	20	17	16	15	14	14	13	13	13	13
			2000									
	20	24	21	18	17	16	15	15	14	14	13	13
	21	25	22	19	18	17	16	15	15	14	14	14
	22	26	23	20	18	17	17	16	16	15	15	15
	23	28	24	21	19	18	17	17	16	16	15	15
	24	29	25	22	20	19	18	18	17	17	16	16
	25	30	26	23	21	20	19	18	18	17	17	17
	26	31	27	24	22	21	20	19	18	18	18	17
	27	32	28	25	23	21	20	20	19	19	18	18
	28	34	29	26	24	22	21	20	20	19	19	19
	29	35	30	26	24	23	22	21	21	20	20	19
	30	36	31	27	25	24	23	22	21	21	20	20
	31	37	32	28	26	25	24	23	22	21	21	20
	32	38	33	29	27	25	24	23	23	22	22	21
	33	40	34	30	28	26	25	24	23	23	22	22
	34	41	36	31	29	27	26	25	24	23	23	22
	35	42	37	32	29	28	27	26	25	24	24	23
	36	43	38	33	30	29	27	26	26	25	24	24
	37	44	39	34	31	29	28	27	26	26	25	24
	38	46	40	35	32	30	29	28	27	26	26	25
	39	47	41	36	33	31	30	29	28	27	26	26
	40	48	42	36	34	32	30	29	28	28	27	26
	41	49	43	37	34	33	31	30	29	28	28	27
	42	50	44	38	35	33	32	31	30	29	28	28
	43	52	45	39	36	34	33	31	30	30	29	28
	44	53	46	40	37	35	33	32	31	30	30	29
	45		47	41	38	36	34	33	32	31	30	30
	46		48	42	39	36	35	34	33	32	31	30
	47		49	43	39	37	35	34	33	32	32	31

TABLE Q 2.2 Equivalent elongation on 5,65 $\sqrt{s_0}$ for test pieces with gauge lengths of 200 mm

Actual per cent. elong. on		(Correspon	nding per	cent. el	ongation	on 5,65	√ So ga	uge lengt	h if cros	s-sections	al area in	mm ² is		
200 mm gauge length	100	150	200	300	400	500	600	700	800	900	1000	1500	2000	2500	3000
10	17	15	14	13	13	12	11	11	11	11	10	10	9	9	8
11	18	17	16	15	14	13	13	12	12	12	11	11	10	10	9
12	20	18	17	16	15	14	14	13	13	13	13	12	11	10	10
13	22	20	19	17	16	16	15	15	14	14	14	13	12	11	11
14	24	21	20	19	18	17	16	16	15	15	15	14	13	12	12
15	25	23	22	20	19	18	17	17	16	16	16	15	14	13	13
16	27	25	23	21	20	19	18	18	18	17	17	16	15	14	14
17	29	26	25	23	21	20	20	19	19	18	18	17	16	15	14
18	30	28	26	24	23	22	21	20	20	19	19	18	17	16	15
19	32	29	27	25	24	23	22	21	21	20	20	18	17	17	16
20	34	31	29	27	25	24	23	23	22	21	21	19	18	18	17
21	35	32	30	28	27	25	24	24	23	23	22	20	19	18	18
22	37	34	32	29	28	27	26	25	24	24	23	21	20	19	19
23	39	35	33	31	29	28	27	26	25	25	24	22	21	20	20
24	40	37	35	32	30	29	28	27	26	26	25	23	22	21	20
25	42	38	36	33	32	30	29	28	28	27	26	24	23	22	21
26	44	40	38	35	33	31	30	29	29	28	27	25	24	23	22
27	45	41	39	36	34	33	31	30	30	29	28	26	25	24	23
28	47	43	41	38	35	34	33	32	31	30	29	27	26	25	24
29	49	45	42	39	37	35	34	33	32	31	30	28	27	25	25
30	50	46	43	40	38	36	35	34	33	32	31	29	28	26	25
31	52	48	45	41	39	37	36	35	34	33	33	30	28	27	26
32		49	46	43	40	39	37	36	35	34	34	31	29	28	27
33		51	48	44	42	40	38	37	36	35	35	32	30	29	28
34		52	49	46	43	41	40	38	37	36	36	33	31	30	29
35			. 51	47	44	42	41	40	38	38	37	34	32	31	30
36			52	48	45	43	42	41	.40	39	38	35	33	32	31
37				50	47	45	43	42	41	40	39	36	34	32	31
38				51	48	46	44	43	42	41	40	37	35	33	32
39				52	49	47	45	44	43	42	- 41	38	36	34	33

or in British units:-

TABLE Q 2.2 Equivalent elongation on $5.65\sqrt{\mathrm{So}}$ for test pieces with gauge lengths of 8 in

Actual per cent. elong. on 8 in		1	Co	rrespond	ing per c	ent. elor	gation o	n 5·65 V	/So gaug	e length	if cross-s	ectional	area in i	nches ² is	:-	14	-
gauge length	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1 · 0	1.2	1.4	1.6	1 · 8	2.0	3.0	4.0
10	18	16	15	14	13	13	12	12	12	11	11	11	10	10	10	9	9
11	20	18	16	15	15	14	14	13	13	13	12	12	12	11	11	10	10
12	22	19	18	17	16	15	15	14	14	14	13	13	13	12	12	11	10
13	24	21	19	18	17	17	16	16	15	15	14	14	14	13	13	12	11
14	25	22	20	19	18	18	17	17	16	16	15	15	15	14	14	13	12
15	27	24	22	21	20	19	19	18	18	17	17	16	16	15	15	14	13
16	29	26	23	22	21	20	20	19	19	18	18	17	17	16	16	15	14
17	31	27	25	23	22	22	21	20	20	19	19	18	18	17	17	16	15
18	33	29	26	25	24	23	22	22	21	21	20	19	19	18	18	17	16
19	35	30	28	26	25	24	23	23	22	22	21	20	20	19	19	18	17
20	36	32	29	28	26	26	25	24	23	23	22	21	21	20	20	18	17
21	38	34	31	29	28	27	26	25	25	24	23	23	22	21	21	19	18
22	40	35	32	30	29	28	27	26	26	25	24	24	23	22	22	20	19
23	42	37	34	32	30	29	28	28	27	26	25	25	24	23	23	21	20
24	44	38	35	33	32	31	30	29	28	28	27	26	25	25	24	22	21
25	45	40	37	34	33	32	31	30	29	29	28	27	26	26	25	23	22
26	47	42	38	36	34	33	32	31	31	30	29	28	27	27	26	24	23
27	49	43	40	37	36	34	33	32	32	31	30	29	28	28	27	25	24
28	51	45	41	39	37	36	35	34	33	32	31	30	29	29	28	26	24
29	53	46	42	40	38	37	36	35	34	33	32	31	30	30	29	27	25
30		48	44	41	40	38	37	36	35	34	33	32	31	31	30	28	26
31		50	45	43	41	40	38	37	36	36	34	33	32	32	31	29	27
32		51	47	44	42	41	39	38	38	37	35	34	33	33	32	30	28
33		53	48	45	43	42	41	40	39	38	37	35	34	34	33	30	29
34			50	47	45	43	42	41	40	39	38	36	36	35	34	31	30
35			51	48	46	45	43	42	41	40	39	38	37	36	35	32	31
36			53	50	47	46	44	43	42	41	40	39	38	37	36	33	32
37				51	49	47	46	44	43	42	41	40	39	38	37	34	33
38				52	50	48	47	46	45	44	42	41	40	39	38	35	34
39					51	50	48	47	46	45	43	42	41	40	39	36	35

length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 per cent proof stress can be calculated.

- (d) The 0,5 per cent proof stress under load is to be calculated from the load corresponding to a total extension of 0,5 per cent of the original gauge length. This extension is to be measured either by the use of a suitable extensometer or by dividers.
- (e) In all cases the rate of increase of stress in the upper half of the elastic range and until the yield load has been reached is not to be greater than 1 kg/mm²/second (0.6 ton/in²/second). After reaching the yield load the rate of straining may be increased to a maximum of 40 per cent of the original gauge length per minute for the determination of the tensile strength.

Tensile Tests at Elevated Temperatures

205 Test pieces used for the determination of lower yield or 0,2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 mm (2 in) and a cross-sectional area of not less than 65 mm² (0·10 in²). Where, however, the dimensions of the product or the test equipment available will not permit this size of test piece being used, the test piece is to be of the largest practicable dimensions.

For materials which show the yield phenomenon, the straining rate in the upper half of the elastic range and during determination of the lower yield stress is to be within the range of 0,1 per cent to 0,3 per cent of the gauge length per minute and should preferably be controlled by reference to a strain pacer or a strain rate meter with a time interval between measurements of strain not exceeding 6 seconds. As an alternative to the use of a strain pacer or a strain rate meter the rate of increase of stress in the elastic range equivalent to the above maximum straining rate may be calculated taking into account the characteristics of the testing machine, the cross-section and gauge length of the test piece. This calculated value can then be used to control the straining rate during testing.

When the 0,2 per cent proof stress is being determined the rate of increase of stress in the upper half of the elastic range and during determination of the proof stress is not to exceed 4 kg/mm²/minute (2.5 ton/in²/minute).

Bend Test Pieces

206 Test pieces for bend tests are to be sheared or machined to the following dimensions:—

Plates and Sections: Plate or section thickness with a minimum width of 35 mm (1·4 in). The rolled surfaces are to be retained.

Thick Plates: When the power of the available testing machine is insufficient to bend a test piece of the full thickness, two test pieces each 25 mm (1 in) thick by 35 mm (1 · 4 in) wide are to be machined. One rolled surface is to be retained on each test piece and this is to be the side tested in tension.

Forgings and Castings: To be machined to a rectangular section 25 mm (1 in) wide by 20 mm (0.75 in) thick. A subsidiary test piece 20 mm (0.75 in) wide by 10 mm (0.4 in) thick is permitted for higher tensile strength steel and tests from rotor forgings. For steel castings a test piece machined to 25 mm (1 in) diameter may also be used.

Rolled Bars: Bars up to and including 25 mm (1 in) diameter are to be tested in full section. For larger diameter bars either a round test piece 25 mm (1 in) diameter or a rectangular test piece 25 mm (1 in) wide by 20 mm (0.75 in) thick is to be machined.

Pipes: The bend test piece is to be cut as a circumferential strip of the full wall thickness and with a width of not less than 35 mm (1·4 in). For thick walled pipes the wall thickness may be reduced to 20 mm (0·75 in) by machining. The test piece is to be bent in the direction of the original curvature.

The sharp edges of all rectangular section bend test pieces may be removed by suitable mechanical means to a radius not exceeding 1.5 mm (0.06 in).

Procedure for Bend Tests

207 This test is to be carried out at ambient temperature and is to consist of bending the test piece by pressure or hammer blows round a suitable former. The diameter of the former and the required angle of bend are to be in accordance with the specific requirements for the material. When an angle of bend of 180° is required, the sides after bending are to be parallel and apart by a distance equal to the diameter of the former specified for the material.

The test is considered to be satisfactory if, after bending as above, the test piece is unbroken and free from cracks and in the case of rolled products is also free from laminations. Small cracks at the edges of rectangular test pieces are to be disregarded.

Impact Tests

208 Test pieces for impact tests are to be either of the Charpy V-notch, Charpy U-notch or Izod types as required in subsequent Sections giving specific requirements for different components and materials.

The test pieces are to be machined to the dimensions and tolerances given in Tables Q 2.3 and Q 2.4.

TABLE Q 2.3

Overall Dimensions and Tolerances for Impact Test Pieces

Designation		Nominal Dimension	Tolerance
CHARPY V-NOTCH AND U-NOTCH			
Length		55 mm	$\pm 0,60 \text{ mm}$
Width Standard		10 mm	$\pm 0.11 \text{ mm}$
Subsidiary Standard		7,5 mm	\pm 0,11 mm
., ., .,		5,0 mm	$\pm 0,05 \text{ mm}$
	***	2,5 mm	±0,05 mm
Thickness " "		10 mm	±0,11 mm
Distance of notch from end of test		27,5 mm	±0,42 mm
	proce	.,,	
Square Izod			
Length Standard 3 notch		130 mm	minimum
2 notch		100 mm	minimum
l notch	***	75 mm	minimum
Width		10 mm	$\pm 0,11 \text{ mm}$
Thickness		10 mm	+0.11 mm
Distance of notch from end of tes	t piece and		
from adjacent notch		28 mm	+0.42 mm
Round Izod		NAME AND ADDRESS OF THE OWNER, TH	
Length Standard 3 notch		5 · 2 in	minimum
2 notch	*** ***	4·1 in	minimum
l notch		3.0 in	minimum
Diameter	*** ***	0·45 in	+0.005 in
Distance of notch from end of tes	t piece and		
from adjacent notch		1.1 in	±0.018 in

TABLE Q 2.4

Dimensions and Tolerances of Notch for all types of Impact Test Pieces

D .:	Charpy V-Notch	and Izod	Charpy U-Notch					
Designation	Nominal Dimension	Tolerance	Nominal Dimension	Tolerance				
Angle of notch	45°	±2°						
Depth below notch	8 mm*	±0,11 mm	5 mm	±0,09 mm				
Root radius	0,25 mm	±0,025 mm	1 mm	±0,07 mm				
Angle between plane of symmetry of notch and the longitudinal axis of the test piece	90°	±2°	90°	±2°				

^{*}For round Izod test piece 0.32 in ± 0.002 in

For material under 10 mm (0.4 in) in thickness, the largest possible size of subsidiary Charpy V-notch or U-notch is to be prepared with the notch cut on the narrow face. Generally, impact tests are not required when the thickness of the material is under 3 mm (0.12 in).

For 2 or 3 notch square Izod test pieces only one notch is to be cut on any one face. Notches on round Izod test pieces are to be similarly orientated.

Where Charpy V-notch or U-notch test pieces are taken from rolled products the notch is to be cut on the face of the test piece which was originally perpendicular to the rolled surface.

The impact test is to consist of either 3 Charpy V-notch or U-notch test pieces or one standard 3 notch Izod test piece (or equivalent 1 or 2 notch test pieces) as may be specified.

Charpy U-notch and Izod impact tests are generally to be carried out at ambient temperature. Charpy V-notch tests may be carried out at ambient or lower temperatures in accordance with the specific requirements given in subsequent Sections. Where the test temperature is other than ambient the temperature of the test pieces is to be controlled to within $\pm 2 \deg C$ for a sufficient time to ensure uniformity throughout the cross-section of the test piece and suitable precautions are to be taken to prevent any significant change in temperature during the actual test. In cases of dispute, ambient temperature is to be considered as $20 + 2^{\circ}C$.

When reporting results the units used for expressing the energy absorbed and the actual testing temperature are to be clearly stated.

Flattening Test on Boiler Tubes and Pipes

209 The test piece is to consist of a piece of tube or pipe with the ends perpendicular to the axis. The length is to be equal to 1,5 times the nominal internal diameter but is to be not less than 10 mm (0·4 in) nor more than 100 mm (4·0 in). Alternatively, the test may be made on the end of a tube or pipe without the test piece being removed, provided that the length flattened is as above. The cut ends of the test piece may be rounded by filing.

The test is to be carried out at ambient temperature and is to consist of flattening the test piece in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two plain parallel and rigid platens which extend over both the full length and the width after flattening of the test piece. Flattening is to be continued until the distance between the platens, measured under load, is not greater than that given in the specific requirements. After flattening the test piece is to be unbroken and free from cracks or other flaws. Small cracks at the ends of test pieces may be disregarded.

For electric resistance welded tubes or pipes the weld is to be placed at the line of maximum bending.

Drift Expanding Test on Boiler Tubes

210 The test piece is to consist of a piece of tube with one end cut perpendicular to the axis. The length is to be equal to 1,5 times the external diameter but not less than 50 mm (2 in). Alternatively, the test may be made on the end of a tube without the test piece being removed. The edges of the end to be tested may be rounded by filing.

The test is to be carried out at ambient temperature and is to consist of expanding the end of the tube symmetrically by means of a hardened conical steel mandrel having a total included angle of between 40° and 60° (see Fig. Q 2.1). The mandrel is to be forced into the test piece until the percentage increase in the external diameter of the end of the test piece reaches the value given in the specific requirements for boiler tubes. The mandrel is to be lubricated but there is to be no rotation of the tube or mandrel during the test.

The expanded portion of the tube is to be free from cracks or other flaws.

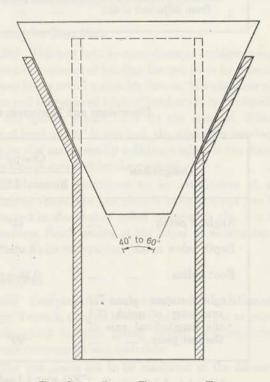


Fig. Q 2.1 Drift Expanding Test

Section 3

ROLLED STEEL PLATES

Scope

301 This Section gives specific requirements for carbon, carbon-manganese and low alloy steel plates intended for use in the construction of boiler or superheater drums or headers, pressure vessels and welded machinery structures. For pressure vessels containing radio-active materials or gases, additional requirements may be specified.

The steel plates are to be manufactured and tested in accordance with the requirements of this Section and the relevant requirements of Q 1 and Q 2. Provision is made for four categories of plates which differ mainly in respect of testing procedures and are intended for the following uses:—

Category I For boilers and pressure vessels where design is based on guaranteed values for elevated temperature properties.

Category II(a) For boilers and pressure vessels where design is based on nominal values for elevated temperature properties which are not required to be proved by test.

Category II(b) For welded machinery structures.

Category III For pressure vessels intended for special low temperature service where the steel is to have guaranteed low temperature Charpy V-notch impact properties. In this case the proposed specification is to be submitted for approval.

Alternatively, steel plates complying with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

Manufacture

302 For Categories I and II the method of deoxidation is to be in accordance with that given in Table Q 3.1. For Category III the method of de-oxidation is to be included in the specification submitted for approval. Silicon killed or aluminium treated steels are to be cast in moulds with efficient feeder heads.

Chemical Composition

303 For Categories I or II the chemical composition of the steel is to comply with the requirements given in Table Q 3.1. This Table also gives details of the grades for each Category.

The chemical composition of steels for Category III is to comply with the approved specification.

Heat Treatment

304 All plates are to be supplied in the condition detailed in Table Q 3.2, unless otherwise agreed. For carbon and carbon-manganese steels an approved procedure for controlled rolling can be accepted instead of a normalising heat treatment. Plates intended for hot forming may be supplied in the "as rolled" condition provided that they are either hot formed in the normalising temperature range or are normalised after hot forming.

If required by the Surveyors or by the fabricator, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test pieces. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

Test Material

305 (a) Category I. Tensile tests at ambient temperature and bend tests are to be taken from one end of each rolled length when the weight is not in excess of 2500 kg (2.5 tons). When the weight exceeds 2500 kg (2.5 tons) these tests are to be taken from both ends.

For applications where the design temperature is in excess of 100° C one elevated temperature tensile test is to be taken from each rolled length. When the rolled length exceeds 2500 kg (2·5 tons) in weight the test piece is to be taken from the end which gave the lower tensile value at ambient temperature. These tensile tests at elevated temperatures are not required when:—

- (i) the reference test temperature is 100°C or less.
- or (ii) the specified minimum value of the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value,
- or (iii) the actual tensile strength at ambient temperature exceeds by at least 4 kg/mm² (2.5 ton/in²) the specified minimum tensile strength. This applies only to carbon and carbon-manganese steels,
- or (iv) the steelmaker has obtained certification of elevated temperature proof stress values, as detailed in 306(d).

Category II (a). Tensile tests at ambient temperature and bend tests are to be taken as for Category I. Tensile tests at elevated temperatures are not required.

Category Π (b). One tensile test piece is to be taken from the thickest piece in each batch of 20 000 kg (20 tons) or less, from the same cast. Where the thicknesses of the pieces

Chemical Composition of Plates, Categories I and II

GRADE OF	TENSIL	E STRENGTH	CATEGORY	METHOD OF			CHEMIC	AL COMPOSITIO	N OF LADLE SAI	MPLES, PER CI	ENT			
STEEL	kg/mm ²	ton/in2		DEOXIDATION	C	Si	Mn	S	P		Residual l	Elements		
	37-47 23·5-29·8 I, II(a), Any except 0,17 max. 0,35 max. 0,40-1,20 0,050 max. 0,050 max		0,050 max.	050 max.										
Carbon	42-52	26 · 7 – 33 · 0	I, II(a), II(b)	Any except rimming	0,20 max.	0,35 max.	0,50-1,30	0,050 max.	0,050 max.	Ni 0,30 max. Cr 0,25 max.		Cr 0,25 max.		
and Carbon-	47-57	29 · 8 – 36 · 2	I, II(a)	Any except rimming (Note 1)	0,20 max. (Note 2)	0,35 max.	0,60-1,40	0,050 max,	0,050 max.		Mo 0,10 max. Cu 0,30 max. Total 0,70 max.			
Manganese	52-62	33.0-39.4	I, II(a)	Any except rimming (Note 1)	0,20 max. (Note 2)	0,50 max.	0,90–1,50	0,050 max.	0,050 max.					
	E		1 4 4	- 120	C	Si	Mn	S	P	Ni	Cr	Мо	Cu	
Low Alloy 1Cr½Mo	44-56	27 - 9 - 35 - 6	I	Silicon killed	0,18 max.	0,15-0,35	0,4-0,8	0,040 max.	0,040 max.	0,30 max.	0,8-1,2	0,4-0,6	0,20 max	
2½Cr1Mo	52-67	33 · 0 - 42 · 5	I	Silicon killed	0,15 max.	0,15-0,35	0,4-0,8	0,040 max.	0,040 max.	0,30 max.	2,0-2,5	0,9-1,1	0,20 max	

Notes: 1. May also contain Niobium 0,08 per cent max.

2. For material over 30 mm (1·2 in) in thickness Carbon 0,22 per cent max.

TABLE Q 3.2

Heat Treatment of Plates

GRADE OF	Tensil	e Strength	CATEGORY I	CATEGORIES II(a) & II(b)	CATEGORY III
STEEL	kg/mm ²	ton/in2			
Carbon and	37-47	23 · 5 – 29 · 8	All thicknesses to be	Plates exceeding 45 mm (1.75 in) in thickness	In accordance with
Carbon- Manganese	42-52	26 · 7 – 33 · 0	normalized	to be normalized	approved specification
	47-57	29 · 8 – 36 · 2	All thicknesses to be	All thicknesses to be	In accordance with
	52-62	33 · 0 – 39 · 4	normalized	normalized	approved specification
Low Alloy 1Cr½Mo	44-56	27 • 9 – 35 • 6	All thicknesses to be normalized (Note 1)		
2 ¹ / ₄ Cr1Mo	52-67	33 · 0 - 42 · 5	All thicknesses to be normalized and tempered		

Note 1. May also be normalized and tempered

within a batch vary by more than 12 mm (0.5 in) an additional test representing the thinner material is to be taken.

One bend test piece is to be taken from each rolled length.

Category III. Tensile tests at ambient temperature and bend tests are to be taken as for Category I and in addition a set of three Charpy V-notch test pieces is to be taken from one end of each rolled length.

(b) Test pieces for tensile tests at ambient and elevated temperatures and for bend tests are to be transverse to the principal direction of rolling and are to be cut from the plate end or ends at approximately quarter width. The axis of fully machined round proportional test pieces is, when the thickness permits, to be co-incident with the quarter thickness of the plate.

Impact test pieces are to be cut from a similar position but are to be parallel to the principal direction of rolling. They are to be machined from material close to one of the rolled surfaces.

- (c) When plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator then the tests at the steelworks are to be made on material which has been cut from the plates and given a normalizing or normalizing and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.
- (d) Cold straightening of material for tensile and impact tests is not permitted.

(e) All test pieces are to be machined in accordance with Q 2 and for tests at ambient temperature the tensile test pieces are to have a cross-sectional area of not less than 150 mm² (0·23 in²).

Mechanical Properties

306 (a) Category I. The results of all tensile tests are to comply with the values given in Table Q 3.3. The lower yield or 0,2 per cent proof stress values at elevated temperatures are to be determined at the reference test temperature given in the order (see Q 101(c)).

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 3.3.

Stress rupture values for design purposes are given in Table Q 3.5.

(b) Category II. The results of all tensile tests at ambient temperature are to comply with the values given in Table Q 3.4.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 3.4.

For design purposes nominal values of the lower yield or 0,2 per cent proof stress at elevated temperatures are given in Table Q 3.4 for carbon and carbon-manganese steels. Stress rupture values are given in Table Q 3.5.

(c) Category III. The results of all the tensile, bend and impact tests are to comply with the approved specification. The Charpy V-notch tests are to be made at or below the reference test temperature given in the order (see Q 101(c)).

TABLE Q 3.3 Mechanical Properties of Plates, Category I

	Grade of	Minimu	Stress kg im for th nm. (Not	ickness	Tensile Strength kg/mm ²	Elongation on 5,65 V So	Bend Test Maximum			Minimum Lower Yield or 0,2% Proof Stress, kg/mm ² (Note 1)								1
	Steel	Up to	Over 16 to 40	Over 40 to 63	Kg/mm²	% Minimum (Note 2)	diameter of former	100° C	150° C	200° C	250° C	300° C	350° C	400° C	450° C	500° C	550° C	600°
C	Carbon and — Carbon- —	24	23	22	37-47	25	2t	17,5	17,0	16,5	15,0	13,5	12,5	11,5	10,0			
'		26	25	24	42-52	23	2t	21,0	20,5	19,5	18,0	16,0	15,0	14,0	12,0			
		30	29	28	47-57	21	3t	25,0	24,0	22,5	20,5	19,0	17,5	16,0	14,0			
	Manganese	36	35	34	52-62	. 20	3t	29,0	28,0	26,0	24,0	22,0	20,5	18,0	16,0			
	Low Alloy 1Cr ₂ Mo	29	28	28	44–56	23	3t			Vo	luas hy s	greemen	t with t	he manu	facturer			
	2½Cr1Mo	32	31	31	52-67	18	3t			v a.	iues by a	greemen	to with the	пе шапи	Tacturer			

t = thickness of bend test piece.

Notes. 1. These values apply only to plates up to 63 mm in thickness. For thicker plates the yield stress or the 0,2 per cent proof stress values are to be reduced by 1 per cent for each 5 mm increase in thickness over 63 mm.

2. For plates over 63 mm in thickness the minimum percentage elongation values are to be reduced by 1.

Grade of

Carbon and

Carbon-

Manganese

Low Alloy

1Cr1Mo

21Cr1Mo

Yield Stress ton/in² Minimum for thickness in inches (Note 1)

> Over Over 0.63 to 1.6 to 1.6 2.5

> > 17.8

20.3 19.7 19.7 33.0-42.5

14.6 14.0

16.5 15.9 15.2

19.1 18.4 17.8

22.2

18.4 17.8

100° C

11.1

24 900

10.8

24 200

150° C 200° C

10.5

23 500

9.5

21 300 19 200

550° C 600° C

Minimum Lower Yield or 0.2% Proof Stress ton/in2 (Note 1)

8.6

250° C 300° C 350° C 400° C 450° C 500° C

17 800 16 400

7.3

6.4

14 200

7.9

t = thickness of bend test piece

- Notes. 1. These values apply only to plates up to 2.5 inches in thickness. For thicker plates the yield stress or the 0.2 per cent proof stress values are to be reduced by 1 per cent for each 0.2 in increase in thickness over 2.5 in.
 - 2. For plates over 2.5 inches in thickness the minimum percentage elongation values are to be reduced by 1.

Elongation

on 5.65 V So

% Minimum (Note 2)

23

21

20

23

18

Tensile

Strength ton/in2

23.5-29.8

26 - 7 - 33 - 0

29 . 8 - 36 . 2

27 - 9-35 - 6

21.6 33.0-39.4

Bend Test

Maximum

diameter of former

2t

528

TABLE Q 3.4 Mechanical Properties of Plates, Category II

Grade of		Stress ka um for th in mm.		Tensile	Elongation on 5,65 V So	Bend Test Maximum			L	ower Yiel	d or 0,2 %	Proof Str	ess kg/mm	² (Note 1)		
Steel	Up to	Over 16 to 40	Over 40 to 63	Strength kg/mm ²	% Minimum (Note 2)	diameter of former	100° C	150° C	200° C	250° C	300° C	350° C	400° C	450° C	500° C	550° C	600° C
0.1. 1	21	20	19	37-47	25	2t	14,8	14,5	14,2	12,8	11,2	9,6	9,4	9,4			HE III
Carbon and	23,5	22,5	21,5	42-52	23	2t	18,0	17,6	17,3	15,8	14,2	12,6	12,3	12,0			
Carbon-	26,5	25,5	24,5	47-57	21	3t 7	21,0	20,8	20,3	18,6	17,0	15,4	14,5	13,5			
Manganese	30	29	28	52-62	20	3t	24,1	23,8	23,1	21,4	19,9	18,3	16,5	15,0			

t = thickness of bend test piece

- Notes. 1. The values for yield stress or 0,2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by test.
 - 2. For plates over 63 mm in thickness the minimum percentage elongation values are to be reduced by 1.

or in British units:-

TABLE Q 3.4 Mechanical Properties of Plates, Category II

Grade of Steel	Minimu	Stress to im for th in inches	ickness	Tensile Strength	Elongation on 5.65 V So	Bend Test Maximum		ma	10-5	Lower Yie	eld or 0 · 2	% Proof S	tress, 1b/i	n² (Note 1)		
Steel	Up to 0.63	Over 0.63 to 1.6	Over 1.6 to 2.5	Strength ton/in ²	% Minimum (Note 2)	diameter of former	100° C	150° C	200° C	250° C	300° C	350° C	400° C	450° C	500° C	550° C	600° C
0 1 1	13-3	12.7	12.1	23 - 5 - 29 - 8	25	2t	21 100	20 600	20 200	18 200	15 900	13 700	13 400	13 400			
Carbon and	14.6	14.3	13.6	26 · 7 – 33 · 0	23	2t	25 600	25 000	24 600	22 500	20 200	17 900	17 500	17 100			
Carbon-	16.8	16.2	15.5	29 · 8 – 36 · 2	21	3t	29 900	29 600	28 900	26 500	24 200	21 900	20 600	19 200			
Manganese	19.1	18.4	17.9	33 · 0 – 39 · 4	20	3t	34 300	33 900	32 900	30 400	28 300	26 000	23 500	21 300			

t = thickness of bend test piece

- Notes. 1. The values for lower yield or 0.2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by test.
 - 2. For plates over 2.5 inches in thickness the minimum percentage elongation values are to be reduced by 1.

TABLE Q 3.5

Average Values for Stress to Rupture in 100 000 hours, Categories I and II

Units: kg/mm²

Temperature °C	Carbon and Carbon-Manganese Steel	1Cr †Mo Steel	2‡Cr 1Mo Stee
350	21,5		
360	19,7		
370	17,9		
380	16,0		
390	14,3		
400	12,5		101
410	10,8		
420	9,4		
430	8,3		
440	7,3		
450	6,5	32,0	
460	5,7	28,4	
470	5,0	25,0	
480	4,4	21,6	21,4
490	3,8	18,3	19,2
500	3,3	15,1	17,2
510	10/2/2	12,4	15,1
520		10,1	13,2
530	0.01	8,0	11,5
540		6,3	9,9
550	DOM	5,0	8,5
560	99	4,1	7,2
570	1001	3,2	6,1
580	- WAE	2,4	5,2
590			4,4
600			3,8

or in British units:-

TABLE Q 3.5

Average Values for Stress to Rupture in 100 000 hours, Categories I and II

Units: lb/in2

Temperature °C	Carbon and Carbon-Manganese Steel	1Cr ∤Mo Steel	2‡Cr 1Mo Steel
350	30 600	ele	S S S
360	28 000		
370	25 400		
380	22 800		
390	20 300		
400	17 800		The same of
410	15 300		100
420	13 400		
430	11 800		
440	10 400		
450	9200	45 500	
460	8000	40 300	
470	7100	35 600	
480	6200	30 700	30 500
490	5400	26 000	27 300
500	4700	21 500	24 400
510	ALL DO .	17 700	21 500
520	1,01	14 300	18 800
530	0,8	11 400	16 400
540	2.0	9000	14 100
550	I I was a	7200	12 100
560		5800	10 300
570		4500	8700
580		3400	7400
590			6300
600			5400

Certification of Lower Yield or 0,2 per cent Proof Stress Values at Elevated Temperatures

(d) For Category I material and other approved grades, as an alternative to taking tensile tests at elevated temperatures from each plate, individual steelmakers may submit for analysis and approval comprehensive test data for a specific grade of steel to demonstrate the lower yield or 0,2 per cent proof stress values at elevated temperatures which can be consistently obtained. This data will be assessed on a statistical basis to determine the 95 per cent lower confidence limits. When a manufacturer is approved on this basis routine tensile tests at elevated temperatures will not be required except for periodic check tests at the discretion of the Surveyors.

Steelmakers requiring this form of certification are to submit the following information and test data from at least 45 plates taken from not less than 10 different casts for each grade of steel.

- (1) Ladle analysis including residual elements,
- (2) Method of de-oxidation,
- (3) Details of heat treatment,
- (4) Results of tensile tests at ambient temperature:— Yield stress, tensile strength and percentage elongation,
- (5) Results of tensile tests at elevated temperatures:— Lower yield or 0,2 per cent proof stress values at 100, 150, 200, 250, 300, 350, 400, 450° C or higher if appropriate for the grade of steel being tested.
- (6) Plate thickness.

The test data are to be representative of the tensile range specified for the grade and also the range of thickness which will be manufactured. For carbon and carbon-manganese steels where there is an overlap in the specified tensile strength range, data submitted for one grade may also be considered for adjacent grades provided the ambient temperature properties comply with the appropriate tensile strength range.

Inspection

307 Inspection is to be carried out in accordance with Q 107.

Repair of Defects

308 The repair of defects by welding at the steelworks is not accepted but proposals for the repair of minor surface defects by the fabricator in accordance with Q 108 will be considered.

Identification

309 Plates are to be identified in accordance with Q 109.

Documentation

310 The manufacturer is to supply the information detailed in Q 110.

Section 4

ROLLED STEEL SECTIONS AND BARS

Scope

401 (a) Hot rolled sections and bars intended for use in boiler, pressure vessel and machinery construction are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

These requirements are related to the intended application and have been sub-divided as follows:—

Rolled Steel Sections and Bars (Boiler Quality)

Paragraphs 402 to 410 give the requirements for rolled sections and bars intended for structural purposes. These include boiler stay bars and bars for the manufacture of bolts which are not subject to dynamic loading or to creep relaxation.

Rolled Steel Bars (Machinery Quality)

Paragraphs 412 to 420 give the requirements for rolled bars intended for the manufacture (by machining operations only) of straight shafting and other important components which are subject to significant dynamic stresses but not subject to creep relaxation. These requirements are applicable only to bars with a diameter not exceeding 250 mm (10 in) and larger items are to be manufactured and tested in accordance with Q 6.

Rolled Steel Bars (Rivet Quality)

Paragraphs 422 to 430 give the requirements for rolled bars intended for the production of rivets and also the tests required from manufactured rivets.

- (b) Rolled bars intended for re-forging are to be manufactured in accordance with the requirements of Q 6 but mechanical tests are not required at the rolling mill.
- (c) Bolts for turbine casings, steam pipe joints and other applications subject to creep relaxation are to be manufactured in accordance with an approved specification.
- (d) In the case of sections and bars intended for special low temperature service, where the steel is to have guaranteed Charpy V-notch impact values at low temperatures, details of the proposed specification are to be submitted for approval.
- (e) At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of material.

In such cases short lengths may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

(f) Alternatively, steel sections complying with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

ROLLED STEEL SECTIONS AND BARS

(Boiler Quality)

402 Rimming or free-cutting steels are not permitted. Any other method of de-oxidation may be used except that for steel with guaranteed low temperature impact properties, the method of de-oxidation is to be in accordance with the approved specification.

Chemical Composition

403 The chemical composition is to comply with the requirements given in Table Q 4.1.

The chemical composition of steels for special low temperature service is to comply with the approved specification.

Heat Treatment

404 Sections and bars may, at the option of the manufacturer be supplied either in the "as rolled" or normalised condition.

Steels with guaranteed low temperature impact properties are to be heat treated in accordance with the approved specification.

Test Material

405 (a) Sections and bars are to be presented for testing in batches containing not more than 50 lengths or 10 000 kg (10 tons) whichever is less. The material in each batch is to be of the same section size and from the same cast. If the sections are supplied in the heat treated condition, the material in each batch is to be subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch type furnace.

At least one tensile test piece is to be taken from material representative of each batch. Bend test pieces are to be taken from each piece (see Q 105(b)).

When required, a set of three Charpy V-notch test pieces are to be taken from material representative of each batch.

(b) All test pieces are to be cut parallel to the direction of rolling. Any straightening of test pieces, which may be required, is to be done cold.

When required, Charpy V-notch impact test pieces are to be cut from the following positions:—

Flats, round and square bar:— At approximately twothirds radius from the
axis of the flat or bar.

Angles and tees:— On thickest leg approximately one-third from
the outer edge.

Joists and channels:— On thickest flange at
approximately one-third
from the outer edge.

Mechanical Properties

406 The results of all tensile tests are to comply with the values given in Table Q 4.2. Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in the above Table.

For steels intended for special low temperature service the Charpy V-notch tests are to be carried out at the reference test temperature given in the order (see Q 101(c)). The results of tensile, bend and Charpy V-notch impact tests are to comply with the approved specification.

Inspection

407 Inspection is to be carried out in accordance with Q 107.

Repair of Defects

408 The repair of defects by welding at the steelworks is not acceptable but proposals for the repair of minor surface defects by the fabricator in accordance with Q 108 will be considered.

Identification

409 Sections are to be identified in accordance with Q 109.

Documentation

410 The manufacturer is to supply the information detailed in Q 110.

ROLLED STEEL BARS (Machinery Quality)

Scope

411 These requirements apply to rolled bars not exceeding 250 mm (10 in) diameter which are intended for the manufacture (by machining operations only) of straight shafting and other important components which are subject to significant dynamic stresses but not subject to creep relaxation.

Larger items are to be manufactured and tested in accordance with Q 6.

TABLE Q 4.1

Chemical Composition of Sections and Bars (Boiler Quality)

Grade of Steel	Tensil	e Strength		Chemical Cor	mposition of la	dle samples—per	centage	
	kg/mm ²	ton/in2	C	Si	Mn	S	P	Residual Elements
Carbon and	42-52	26 · 7 – 33 · 0	0,20 max.	0,35 max.	0,50-1,30	0,050 max.	0,050 max.	Ni 0,30 max. Cr 0,25 max.
Manganese	47-57	29 · 8 – 36 · 2	0,20 max. (Note 1)	0,35 max.	0,60-1,40 (Note 2)	0,050 max.	0,050 max.	Mo 0,10 max. Cu 0,30 max. Total 0,70 max.

Notes. 1. For material over 30 mm (1.2 in) in thickness. Carbon 0,22 per cent max.

2. For sections used in welded machinery structures and for boiler stay bars, $C + \frac{Mn}{6}$ is not in general to exceed 0,41 per cent.

TABLE Q 4.2

Mechanical Properties of Sections and Bars (Boiler Quality)

Grade of Steel		ld Stress kg/mm² for meter in mm (Note		Tensile Strength	Elongation on 5,65 \sqrt{so}	Bend Test Max. diameter
	Up to 16	Over 16 to 40	Over 40 to 63	ag/iiiii=	% Minimum (Note 2)	of former
Carbon and Carbon-	23,5	22,5	21,5	42-52	23	2t
Manganese	26,5	25,5	24,5	47-57	21	3t

t = thickness of bend test piece.

Notes. 1. These values apply only to material with a thickness or diameter less than 63 mm. For material over 63 mm the yield stress values are to be reduced by 1 per cent for each 5 mm increase in thickness or diameter over 63 mm.

2. For material over 63 mm in thickness or diameter the minimum elongation values are to be reduced by 1.

or in British units:-

TABLE Q 4.2

Mechanical Properties of Sections and Bars (Boiler Quality)

Grade of Steel		eld Stress ton/in2 for neter in inches (Note		Tensile Strength	Elongation on 5.65 \sqrt{so}	Bend Test Max. diamete
	Up to 0.63	Over 0.63 to 1.6	Over 1 · 6 to 2 · 5		% Minimum (Note 2)	of former
Carbon and Carbon-	14.6	14.3	13.6	26 · 7-33 · 0	23	2t
Manganese	16.8	16.2	15.5	29 · 8-36 · 2	21	3t

t = thickness of bend test piece.

Notes. 1. These values apply only to material with a thickness less than 2.5 in. For material over 2.5 in the yield stress values are to be reduced by 1 per cent for each 0.2 in increase in thickness or diameter over 2.5 in.

2. For material over 2.5 inches in thickness or diameter the minimum elongation values are to be reduced by 1.

Manufacture

412 Bars are to be manufactured in accordance with the requirements of Q 602. The use of rimming, free-cutting or semi-killed steel is not acceptable.

Chemical Composition

413 The chemical composition is to comply with the requirements of Q 603.

Heat Treatment

414 Bars are to be supplied in the normalized or other approved condition of heat treatment.

Test Material

- 415 Material is to be presented for test in batches. A batch is to consist of either:—
- (i) material from the same piece or rolled length (see Q 105(b)) provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge.
- or (ii) bars of the same diameter and cast, heat treated in the same furnace charge and with a total weight not exceeding 1000 kg (1 ton).

One tensile and one bend test piece are to be taken from each batch, and are to be machined in accordance with Q 2.

Mechanical Properties

416 The results of all tensile tests are to comply with the requirements of Q 606. Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.3.

Inspection

417 Inspection is to be carried out in accordance with Q 107.

Repair of Defects

418 The repair of defects by welding is not permitted.

Identification

419 The rolled bars are to be identified in accordance with Q 109.

Documentation

420 The manufacturer is to supply the information detailed in Q 110.

ROLLED STEEL BARS

(Rivet Quality)

Scope

421 These requirements apply to rolled bars intended for the production of rivets. The tests required for manufactured rivets are also given.

Manufacturer

422 The steel is to be non-rimming and is to be free from excessive central segregation.

Chemical Composition

423 The chemical composition is to comply with the following:—

 Carbon
 0,22% max.

 Silicon
 0,35% max.

 Manganese
 0,4/1,0%

 Sulphur
 0,050% max.

 Phosphorus
 0,050% max.

Heat Treatment

424 Bars and rivets are to be supplied in the "as rolled" or "as manufactured" condition.

Test Material

425 (a) Bars are to be presented for test in batches. A batch is to consist of bars rolled from one cast and the total weight of the batch is not to exceed 10 000 kg (10 tons).

From each batch one tensile test piece is to be selected and prepared in accordance with Q 2. In addition, one sample for sulphur print and one dump test piece is to be selected from each batch. The length of the dump test piece is to be equal to twice the diameter.

(b) From each consignment of manufactured rivets, at least three samples are to be selected for the bend and flattening tests described in 428 and for sulphur prints.

Mechanical Properties

426 The tensile test is to be made in accordance with Q 2 and is to give a value between 40 and 48 kg/mm² (25·4 and 30·5 ton/in²). The elongation is to be not less than 26 per cent.

Sulphur Prints

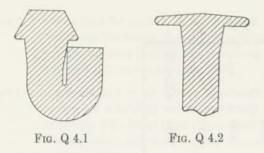
427 Sulphur prints for bars and from manufactured rivets are to show that the material is free from significant central segregation.

Dump, Bending and Flattening Tests

428 The dump test pieces are to withstand being compressed, when cold, to half their length without fracture.

Sample rivets are to withstand being bent cold and hammered until the two parts of the shank touch as shown in Fig. Q 4.1, without fracture.

On other samples the rivet heads are to be flattened, while hot, until the diameter is 2,5 times the diameter of the shank as shown in Fig. Q 4.2, without cracking at the edges.



Identification

429 Bars and manufactured rivets are to be identified in accordance with Q 109.

Documentation

430 The manufacturer is to supply the information and certificates detailed in Q 110.

Section 5

STEEL CASTINGS

Scope

501 (a) Important steel castings intended for use in boiler, pressure vessel and machinery construction are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

The requirements for castings intended for pressure containment or for general machinery construction are given in 501 to 510. Steel castings for crank shafts are to comply with the requirements given in 511 to 520. The requirements for steel propeller castings are given in 521 to 530. Reference should be made to Q 8 for the requirements relevant to cast iron crank shafts and to Q 9 for copper alloy propellers.

Where small and identical castings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the manufacturer.

CASTINGS FOR PRESSURE CONTAINMENT AND GENERAL MACHINERY CONSTRUCTION

(b) The requirements in 502 to 510 are primarily intended for castings such as valve bodies and fittings for boilers and pressure vessels, where the design pressure is in excess of 10 kg/cm² (150 lb/in²), turbine casings and associated castings. Castings for general machinery construction, excluding crank shafts and propellers, are also to be manufactured and tested to these requirements.

Provision is made for four categories of castings which differ mainly in respect of testing procedures and are intended for the following uses:—

- Category I Where design is based on guaranteed values for elevated temperature properties.
- Category II(a) Where design is based on nominal values for elevated temperature properties, which are not required to be proved by test.
 - II(b) Castings for general machinery construction.
- Category III For special low temperature service where
 the steel is to have guaranteed low
 temperature Charpy V-notch properties.
 In this case the proposed specification is
 to be submitted for approval.

Alternatively, steel castings complying with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

Manufacture

502 All castings are to be made at foundries approved by the Committee.

Steel is to be manufactured in accordance with Q102 (a). All flame cutting or scarfing to remove surplus metal is to be completed before final heat treatment of the casting and pre-heating is to be applied when necessary. Alloy steel castings are generally to be given a preliminary annealing heat treatment prior to flame cutting or scarfing. The affected areas are to be ground smooth.

Chemical Composition

503 For Categories 1 and II the chemical composition is to comply with the requirements given in Table Q 5.1.

Where it is proposed to use steels of higher carbon content or alloy steels not specified in Table Q 5.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

The chemical composition of castings for Category III is to comply with the approved specification.

Heat Treatment

- 504 (a) Steel castings are to be uniformly heated to a temperature above the upper critical point to refine the grain structure and are to be:—
 - fully annealed by cooling slowly in the furnace in a uniform manner,
 - or (ii) normalized by cooling in air,

TABLE Q 5.1

Chemical Composition of Castings for Pressure Containment and General Machinery Construction

0 1 10	Tensil	e Strength			C	hemical Co	mposition	of Ladle Sar	nples—per cer	it		
Grade of Steel	kg/mm ²	ton/in2	C max.	Si	Mn	S max.	P max.	Ni max.	Cr	Mo	Cu max.	V
0.1	41–52	26 · 0 – 33 · 0	0,20	0,15-0,60	0,50-1,00	0,050	0,050	0,40	0,25 max.	0,15 max.	0,30 (Note 1)	-
Carbon	44-55	27 - 9 - 34 - 9	0,25	0,15-0,60	0,60-1,20	0,050	0,050	0,40	0,25 max.	0,15 max.	0,30 (Note 1)	
Carbon- Manganese	45-55	27 · 9 – 34 · 9	0,17	0,15-0,60	0,90-1,60	0,050	0,050	0,40	0,25 max.	0,15 max.	0,30 (Note 1)	-
½Mo	44-60	27 · 9 – 38 · 1	0,25	0,15-0,50	0,50-1,00	0,050	0,050	0,40	0,25 max.	0,40-0,70	-0,30	-
1Cr−½Mo	47–70	29 · 8 - 44 · 5	0,23	0,15-0,60	0,50-0,80	0,050	0,050	0,40	1,00-1,50	0,45-0,65	0,30	_
2½Cr-1Mo	47-70	29 · 8 – 44 · 5	0,20	0,15-0,60	0,40-0,70	0,050	0,050	0,40	2,00-2,75	0,90-1,20	0,30	-
½Cr−½Mo−½V	52-70	33 · 0 - 44 · 5	0,18	0,15-0,50	0,40-0,80	0,050	0,050	0,40	0,25-0,50	0,50-0,70	0,30	0,22-0,30

Note 1. Total residual elements 0,80 per cent maximum.

- or (iii) normalized by cooling in air followed by a tempering treatment. For carbon and carbon-manganese steel castings this tempering temperature is to be not less than 600°C.
- or (iv) a combination of the above treatments consisting of annealing or homogenizing at a relatively high temperature as a preliminary refining treatment to subsequent normalizing and tempering.
- (b) All alloy steel castings are to be heat treated as in (iv) above at temperatures suitable for the chemical composition and specified mechanical properties.
- (c) Turbine casings and castings of structural importance, e.g., castings for engine bedplates, are to be heat treated by methods (i), (iii), or (iv) as above. After either full annealing as in (i), or tempering, as in (iii) or (iv), the castings are to be furnace cooled to a temperature of 200°C or less.
- (d) When it is proposed to adopt other heat treatments full details are to be submitted for approval.

Test Material

505 (a) Test material is to be cast attached to each casting at positions agreed between the manufacturer and Surveyor. In all cases both the test material and the casting are to be identified by the Surveyor before separation.

When a number of castings, each less than 500 kg (1100 lb) in weight, are produced from one cast and they are heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

- (b) The test material is not to be detached from the casting it represents until all heat treatment has been completed.
- (c) Category I. At least one tensile and bend test is to be made at ambient temperature for each casting. When large castings are made from more than one cast of steel or are of complex design, the number and location of test material is to be agreed with the Surveyor.

A tensile test at elevated temperature is to be made for each casting, in accordance with Q 205, except when:—

- (i) the reference test temperature is 100°C or less,
- (ii) the specified minimum value for the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value.

- (d) Category II. Test material is to be provided for the tests specified in 505(c), except that tensile tests at elevated temperatures are not required.
- (e) Category III. Test material is to be provided for the tests specified in 505(d) and for one set of Charpy V-notch test pieces.
- (f) The dimensions of the tensile and bend test pieces are to comply with Q 2. Test pieces for tensile tests at ambient temperature are to have a diameter of not less than 14 mm (0.564 in).

Impact test pieces are to be machined in accordance with Q 2.

Mechanical Properties

506 (a) Category I. The results of all tensile tests at ambient temperature and the lower yield or 0,2 per cent proof stress values at the reference test temperature given in the order are to comply with the values given in Table Q 5.2.

Bend test pieces are to withstand being bent through an angle of 120° round a former having a diameter not greater than that specified in Table Q 5.2.

(b) Category II. The results of tensile tests at ambient temperature are to comply with the values given in Table Q 5.2. For design purposes this Table also contains nominal values of yield or 0,2 per cent proof stress values at elevated temperatures for carbon and carbon-manganese steels.

Bend test pieces are to withstand being bent through an angle of 120° round a former having a diameter not greater than that specified in Table Q 5.2.

- (c) Category III. The Charpy V-notch tests are to be made at or below the reference test temperature given in the order. The results of the tensile, bend and Charpy V-notch tests are to comply with the approved specification.
- (d) If for any reason after testing as above, a casting is given a further full annealing or normalizing and tempering heat treatment, e.g., after weld repairs, then the original tests are to be disregarded and further complete mechanical tests are to be made.

Inspection

507 (a) The manufacturer is expected to make any tests necessary to prove the casting technique for prototype castings.

When castings are produced in regular quantities the manufacturer is expected to make periodical examinations to verify the continued efficiency of the manufacturing technique and the Surveyor is to be given the opportunity to witness these tests.

TABLE Q 5.2

Mechanical Properties of Castings for Pressure Containment and General Machinery Construction

Grade of Steel	Yield Stress Minimum	Tensile Strength kg/mm ²	Elonga- tion on 5,65 V So	Reduct- tion of Area	Bend Test, Maximum dia, of	Minimum lower yield or 0,2% proof stress, kg/mm ²					g/mm²	
HE I	kg/mm ²	kg/mm*	% Mini- mum	% Mini- mum	Former	100°C	150°C	200°C	250°C	300°C	350°C	400°C
CATEGORY I	N 7%		1 11									
Carbon	22,5	41-52	22	35	, 3t	18,3	17,6	17,0	15,9	14,2	13,4	12,9
Carbon	24,5	44-55	22	35	3t	20,4	18,9	18,6	17,3	16,0	15,0	14,0
Carbon-							1 1 1					
Manganese	24,5	44–55	22	35	3t	20,4	18,9	18,6	17,3	16,0	15,0	14,0
$\frac{1}{2}$ Mo	24,0	44-60	18	30	3t		*					
$1\mathrm{Cr}{-\frac{1}{2}\mathrm{Mo}}$	26,0	47-70	17	30	3t		** 1					
2½Cr-1Mo	26,0	47-70	17	30	6t		Value	s by agreer	nent with	the manufa	cturer	
$\frac{1}{2}$ Cr $-\frac{1}{2}$ Mo $-\frac{1}{4}$ V	29,0	52-70	17	30	6t							
CATEGORY II		IT	Tital	Tig.		FFF	Lower	yield or 0,2	% proof stres	ss, kg/mm² (l	Note 1)	
Carbon	21,0	41-52	22	35	3t	16,9	16,2	15,9	14,6	12,9	11,9	11,5
Carbon	22,5	44-55	22	35	3t	18,3	17,3	17,0	15,6	14,2	13,2	12,9
Carbon- Manganese	22,5	44-55	22	35	3t	18,3	17,3	17,0	15,6	14,2	13,2	12,9

t = thickness of bend test piece.

Note 1. These values are included for design purposes and do not require to be proved by test.

MATERIALS FOR BOILERS, PRESSURE VESSELS AND MACHINERY

Grade of Steel	Yield Stress Minimum	Tensile Strength	Elonga- tion on 5.65 V So	Reduc- tion of Area	Bend Test Maximum		Minimun	n lower yield	or 0 · 2 % pro	oof stress— t	on/in ² lb/in ²	
	ton/in ²	ton/in2	% Mini- mum	% Mini- mum	dia, of Former	100°C	150°C	200°C	250°C	300°C	350°C	400°C
CATEGORY I												
Carbon	14.3	26 · 0 – 33 · 0	22	35	3t	11·6 26 000	11·2 25 000	10·8 24 200	10·1 22 600	9·0 20 200	8·5 19 100	8·2 18 300
Carbon	15.5	27 - 9 - 34 - 9	22	35	3t }	12.9	12.0	11.8	11.0	10.2	9.5	8.9
Carbon- Manganese	15.5	27 · 9 – 34 · 9	22	35	3t	29 000	26 900	26 500	24 600	22 800	21 300	19 900
½Mo	15.2	27 · 9 – 38 · 1	18	30	3t					301		
1Cr−½Mo	16.5	29 · 8 - 44 · 5	17	30	3t		Volue	hy sareer	nent with t	the manufa	cturer	
$2\frac{1}{4}$ Cr1-Mo	16.5	29 · 8 - 44 · 5	17	30	6t		v aluc.	s by agreer	none with	no manura	ovaror	
$\frac{1}{2}$ Cr $-\frac{1}{2}$ Mo $-\frac{1}{4}$ V	18.4	33 · 0 - 44 · 5	17	30	6t							
CATEGORY II							Lower	yield or 0.2	% proof stres	s, lb/in² (No	te 1)	
Carbon	13.3	26 · 0 – 33 · 0	22	35	3t	24 000	23 000	22 600	20 800	18 300	16 900	16 400
Carbon	14.2	27 · 9 – 34 · 9	22	35	3t]							
					>	26 000	24 600	24 200	22 200	20 200	18 800	18 30
Carbon- Manganese	14.2	27 · 9 – 34 · 9	22	35	3t							

t = thickness of bend test piece

NOTE 1. These values are included for design purposes and do not require to be proved by test.

Table Q 5.2

(b) All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. The surface finish is to be in accordance with good practice and any specific requirement of the Enginebuilder. Before examination, the surfaces must not be hammered, peened or treated in any way which may obscure defects.

Turbine casings are to be examined by magnetic particle method in, at least, all areas containing changes of section and where surplus metal has been removed by flame cutting. Where component castings are to be welded together to form a turbine casing, the material in way of the weld preparations in the component castings is to be examined by radiography. This examination is to be carried out prior to welding.

Castings of structural importance, which in service are subject to significant fatigue loading conditions, e.g., castings for engine bedplates, are also to be examined by magnetic particle methods at positions of high stress.

In all cases supplementary examinations by radiography, ultrasonic or other approved methods of non-destructive testing in order to determine the soundness of the castings may also be requested. This examination should include verification of wall thickness, where appropriate. When such examination is to be carried out, it should be at positions, mutually agreed by the Surveyor, manufacturer and Enginebuilder, where experience shows that cavities, contraction cracks or other defects are most likely to occur. For piston head and cylinder cover castings the manufacturer is to provide the Surveyor with a signed statement that non-destructive testing by an approved procedure has been carried out with satisfactory results. Details of the procedure used are to be stated.

(c) The Surveyor is to examine each large casting, including piston head and cylinder cover castings, before final acceptance at the foundry.

Repair of Defects

508 (a) When defects are found in a casting these are to be removed by grinding or by chipping and grinding. Flame scarfing or arc-air gouging may also be used provided that pre-heating is employed when necessary and that the surfaces of the resulting depressions are subsequently ground smooth. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can, at the Surveyor's discretion, be accepted provided these are blended by grinding.

(b) Proposals to repair a defective casting by welding are to be submitted to the Surveyor before work is commenced. The Surveyor is to satisfy himself that the number and size of the defects are such that the casting can be efficiently repaired.

When it has been agreed that the casting can be repaired the procedure is to be in accordance with Q 108 and the area is to be prepared in a form suitable for welding. All castings in alloy steels and, if necessitated by the shape, castings in carbon or carbon-manganese steels are to be given a preliminary refining heat treatment prior to carrying out weld repairs. An electric arc welding process is to be used and the weld deposit is to have properties similar to and in no way inferior to the parent metal. Welding of the affected parts is to be undertaken by a procedure the essential elements of which have been tested previously by the manufacturers and approved by the Surveyor. The welding is to be done under cover in positions free from draughts and adverse weather conditions by competent welders with adequate supervision.

After welding, the castings are to be suitably heat treated either by annealing, normalizing and tempering or stress relieving at a temperature of not less than 600° C. The type of heat treatment employed will be dependent on the size, position and nature of the defects. On completion of heat treatment, the weld repairs and adjacent metal are to be ground smooth and proved by a suitable method of magnetic particle inspection. Subject to the approval of the Surveyor, a local stress relieving heat treatment may be carried out where the area involved is small and machining of the casting has reached an advanced stage.

Identification

509 Castings are to be identified in accordance with Q 109.

Documentation

• 510 The manufacturer is to supply the information detailed in Q 110 and is to provide the Surveyor with a statement and/or sketch detailing the extent and location of the welded repairs made to each casting together with details of the heat treatment carried out at all stages.

CASTINGS FOR CRANK SHAFTS

Scope

511 Steel castings for crank shafts are to be manufactured and tested in accordance with 511 to 520 and the relevant parts of Q 1 and Q 2.

Alternatively, steel castings which comply with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

Manufacture

512 Castings are to be manufactured in accordance with 502.

The castings are to be produced by an approved method.

Chemical Composition

513 The chemical composition of ladle samples is to be within the following limits:—

Carbon	0,40% Max.	Copper	0,40% Max.
(see Note)	Nickel	0,40% Max.
Silicon	0,15-0,60%	Chromium	0,40% Max.
Manganese	0,60% Min.	Molybdenum	0,20% Max.
Sulphur	0,040% Max.	Total (Cu+N	Ni+Cr+Mo)
Phosphorus	0,040% Max.		1,0% Max.

Note. Weld repairs will not be permitted when the carbon content of the steel exceeds 0,30% or its carbon equivalent, given by

$$C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$
, exceeds 0,65%

(See Chapter R(H) for further requirements).

Where it is proposed to use steel of higher carbon content or alloy steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

Heat Treatment

514 Castings are to be heat treated in accordance with methods (i), (iii) or (iv) of 504(a). After either full annealing, as in (i) or tempering, as in (iii) or (iv) the castings are to be furnace cooled to a temperature of 200°C or less.

Test Material

515 (a) The test material is to be provided as an integral part of each casting. At least one tensile and one bend test piece are required from each casting.

(b) Test pieces are to be prepared in accordance with Q 2. The diameter of the tensile test piece is to be not less than 14 mm (0.564 in) unless otherwise agreed.

Mechanical Properties

516 The tensile strength is to comply with the range specified in the order which is not to exceed 11 kg/mm² $(7 \cdot 0 \text{ ton/in}^2)$ within the general limits of 44 and 65 kg/mm² $(27 \cdot 9 \text{ and } 41 \cdot 3 \text{ ton/in}^2)$.

The yield stress is to be not less than half the actual tensile strength.

The elongation and reduction of area values are to comply with the values given in Table Q 5.3 appropriate to the actual tensile strength.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than two times the thickness of the test piece. Where the actual tensile strength of the steel is in excess of 55 kg/mm² (34·9 ton/in²) the diameter of the former may be increased to three times the thickness of the test piece.

Inspection

517 (a) The manufacturer is to make any tests necessary to prove the casting technique for prototype castings.

The Surveyor is to examine each casting before final acceptance at the foundry.

(b) Crank web and combined web and pin castings are to be examined by magnetic particle methods on all surfaces. For this purpose "as cast" surfaces are to be cleaned and prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. Before examination, the surfaces must not be hammered, peened or treated in any way which may obscure defects.

Any irregularities on surfaces which may interfere with the detection of defects should be smoothed by local grinding. It is recommended that a preliminary examination

TABLE Q 5.3

Mechanical Properties of Castings for Crank shafts

Actual T	ensile Strength	Elongation on	Reduction of area		
kg/mm²	ton/in2	5,65 $\sqrt{\text{So}}$ % minimum	% minimum		
Over 44 to 50	Over 27.9 to 31.8	24	40		
,, 50 to 55	,, 31·8 to 34·9	22	35		
,, 55 to 60	,, 34·9 to 38·1	19	30		
., 60 to 65	,, 38·1 to 41·3	17	30		

should be carried out before final heat treatment but all machined surfaces are to be examined in the finished condition by suitable magnetic particle methods.

Manufacturers are to carry out an ultrasonic test on each casting and are to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

Repair of Defects

518 (a) When defects are found in a casting these are to be removed by grinding or by chipping and grinding. Flame scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting depressions are subsequently ground smooth. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can, at the Surveyor's discretion, be accepted provided these are blended by grinding.

(b) The acceptance of repair by welding is subject to special consideration and any action is to be in accordance with the provisional Rules for repairs by welding to steel castings for crank shafts contained in Chapter R(H).

Identification

519 Castings are to be identified in accordance with Q 109.

Documentation

520 The manufacturer is to supply the information detailed in Q 110. In addition the Surveyor is to be provided with:—

- (i) a statement and/or sketch detailing the extent and location of all welded repairs made to each casting together with details of the heat treatment carried out at all stages.
- (ii) a certificate of ultrasonic examination as required by 517(b).

CASTINGS FOR PROPELLERS

Scope

521 Steel castings for propellers may be made in carbon, low alloy or stainless steel and are to be manufactured and tested in accordance with 521 to 530 and the relevant parts of Q 1 and Q 2. These only give outline requirements and details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

In this Section the term "severe ice service" is intended to indicate use in icebreakers or ships with Class 1*, Class 1, Class IA Super, Class IA, Class IB or Class IC Ice strengthening.

Manufacture

522 Castings are to be manufactured in accordance with 502. Ferritic steel for propellers intended for severe ice service is to be made by a fine grain practice.

Chemical Composition

523 The chemical composition is to comply with the approved specification.

Heat Treatment

524 Castings are to be heat treated in accordance with 504(a) and with the approved specification.

Test Material

525 (a) Test material is to be provided integral with the hub of propeller castings and with the flange or propeller blade castings.

At least one tensile and one bend test piece are to be taken from each casting. In addition, a set of Charpy V-notch test pieces is to be taken from all carbon or low alloy steel castings intended for severe ice service and from all ferritic or martensitic type stainless steel castings. Impact tests are not required from carbon or low alloy steel castings intended for general service or from austenitic stainless steel castings regardless of service.

(b) All test pieces are to be prepared in accordance with Q 2. The diameter of the tensile test piece is to be not less than 14 mm (0.564 in) unless otherwise agreed.

Mechanical Properties

- 526 (a) The results of all tensile and bend tests are to comply with the approved specification.
- (b) The Charpy V-notch tests are to be made at or below the following temperatures:—

Carbon, low alloy, ferritic or martensitic type stainless steel propellers intended for severe ice service:—test temperature -10° C.

Ferritic or martensitic type stainless steel propellers intended for general service:—test temperature 0°C.

The average value for the Charpy V-notch tests is to be not less than 2,1 kg m (15 ft lb). When the average result fails to meet this value, retests in accordance with Q 106(b) may be carried out, irrespective of the actual average value obtained.

The results of the retests are to be added to the original values and the average is to be not less than 2,1 kg m (15 ft lb). For martensitic 13 per cent chromium steel propeller castings, special consideration will be given to acceptance if the average value obtained is not less than 1,4 kg m (10 ft lb).

Inspection

527 The Surveyor is to examine each casting before final acceptance at the foundry. The surfaces of the blade roots are to be examined by magnetic particle methods or in the case of austenitic stainless steel by dye penetrant methods.

Repair of Defects

528 The removal of minor surface defects by grinding and weld repairs are to be carried out in accordance with the requirements of 508.

Identification

529 Castings are to be identified in accordance with Q 109.

Documentation

530 The manufacturer is to supply the information detailed in Q 110 and is to provide the Surveyor with a statement and/or sketch detailing the extent and location of the repairs of welding made to each casting together with details of the heat treatment carried out at all stages.

Section 6

STEEL FORGINGS

Scope

601 Important steel forgings intended for use in boilers, pressure vessels and machinery construction are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

In this Section the term "severe ice service" is intended to indicate use in ice breakers or for ships with Class 1* or Class 1 Ice Strengthening.

Requirements for general forgings including screw shafts for severe ice service are given in 601 to 610. Requirements for the following particular forgings are given in the sub-sections indicated:—

	Paragraphs
Crank shaft forgings	611 to 620
Gear forgings	621 to 630
Turbine forgings	631 to 640
Forgings for boilers and	
pressure vessels	641 to 650

The requirements for shafts machined from hot rolled bars are given in Q 4.

Where small and identical forgings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the manufacturer.

GENERAL FORGINGS

Manufacture

- 602 (a) The forgings are to be manufactured from killed steel. Screw shafts intended for severe ice service and other forgings for low temperature service are to be made from grain controlled steel.
- (b) When forgings are made from ingots, or from blooms forged from ingots, the ingots are to be cast in metal moulds with the larger cross-section uppermost and with efficient feeder heads. The forgings are to be gradually and uniformly hot worked and are to be brought as nearly as possible to the finished shape and size. Where practicable they are to be worked so as to cause metal flow in the most favourable direction having regard to the mode of stressing in service. Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

Unless otherwise approved the maximum sectional area of any part of a forging (as forged) is not to exceed:—

- ¹₃A where the length of any section is greater than its diameter,
- ²/₃A where the length of any section is less than its diameter (e.g., a collar),
- A is the average sectional area of the ingot or of the ingot after upsetting if such an operation is involved.
- (c) When forgings are made from rolled products the maximum sectional area of a forging (as forged) is not to exceed:—
 - (i) when made from products rolled from ingots cast large end uppermost with efficient feeder heads.
 - ¹/₄A where the length of any section is greater than its diameter,
 - or ½A where the length of any section is less than its diameter (e.g., a collar),
 - or (ii) when made from products rolled from other types of ingots,
 - ¹A where the length of any section is greater than its diameter,
 - or $\frac{1}{3}A$ where the length of any section is less than its diameter (e.g., a collar),
 - A is the average cross-sectional area of the original ingot.
- (d) Disc or ring type forgings are to be made from pieces which have been hot cut or machined from a billet, bloom or ingot. The thickness of any part of a disc (as forged or as stamped) is to be not more than:—

one-half of the original length of the piece when this has been cut from a billet or bloom, or one-third of the original length of the piece when this has been cut from an ingot.

(e) The shaping of forgings or thick slabs by flame cutting is to be undertaken in accordance with a procedure approved by the Surveyor. Where possible, flame cutting is to be carried out before the heat treatment operation of 604. Pre-heating is to be employed when necessitated by the thickness and/or composition of the steel.

For machinery parts that are subjected to significant fatigue stresses during service, a depth of at least 7,5 mm (0·3 in) is to be removed by machining from all flame cut surfaces. If required by the Surveyor, selected areas of such machined surfaces are to be prepared and then examined by magnetic crack detection or other equivalent method to his satisfaction.

Chemical Composition

603 (a) For forgings in carbon and carbon-manganese steels and which are not intended for welding, the chemical composition of the ladle sample is to comply with the following:—

Carbon 0,50% max.

Silicon 0,10% to 0,45%

Manganese 0,30% to 1,5%

Sulphur 0,050% max.

Phosphorus 0,05% max.

When it is proposed to use a steel of higher carbon content, or an alloy steel, details of the proposed composition, heat treatment and properties are to accompany the plans which are submitted for approval by the builder.

(b) Forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component are to be of weldable quality with a carbon content generally not exceeding 0,23 per cent. Where the carbon content exceeds 0,23 per cent, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

Heat Treatment

604 All forgings are to be fully heat treated before being put into service. Procedures must be such as to ensure that if full treatment is not carried out by the forgemaster adequate provision with regard to test material is to be made for any treatment to be carried out at a later stage.

Forgings are to be heated to a uniform temperature above the upper critical point to refine the grain and are to be:—

- (i) Fully annealed by cooling slowly in the furnace in a uniform manner,
- or (ii) normalized by cooling in air followed by a

tempering treatment to relieve internal stresses if the diameter of the body of the forging is equal to or greater than the values given in Table Q 6.1. Smaller diameter forgings may also be tempered after the normalizing heat treatment at the option of the forgemaster,

or (iii) hardened by quenching in oil followed by tempering. Unless otherwise agreed, all large forgings are to be rough machined prior to the hardening heat treatment.

Where it is proposed to use other methods for hardening, full details are to be submitted for approval.

TABLE Q 6.1

Dimensions of Forgings to be Tempered after

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Over	Up to and including	Equivalent Diameter of Body of Forging	
0,40	0,50	400 mm (16 in)	
0,35	0,40	500 mm (20 in)	
0,30	0,35	700 mm (28 in)	
0,25	0,30	900 mm (35 in)	
0,25	1000 mm (39 in)		

Test Material

605 (a) Test material is to be provided integral with the forging and with a cross-sectional area of not less than that of the main part of the forging. At least one tensile and one bend test are to be taken from each forging, except where both the weight and length are in excess of 4000 kg (4 tons) and 3 m (10 ft) respectively when tensile and bend tests are to be taken from each end. These limits refer to the "as forged" weight and length but excluding the test material.

(b) When a forging is subsequently divided into a number of items all of which are heat treated together in the same furnace then for test purposes this may be considered as one forging and the test material required is to be related to the total length and weight of the original forging.

Where a number of separate forgings are made from one cast of steel and are heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

(c) Tensile and bend test pieces are to be cut longitudinally or parallel to the direction of principal grain flow. Where test pieces cannot reasonably be provided in the longitudinal direction they may be cut in a transverse direction.

(d) The dimensions of the tensile test pieces are to comply with Q 2 and they are to have a diameter of not less than 14 mm (0.564 in) except where the dimensions of the forging will not permit this diameter of test piece being prepared. In such cases the test piece is to be of the largest practicable diameter.

Bend test pieces are to be machined in accordance with Q 2, the subsidiary test piece (20 mm by 10 mm) being used when the specified minimum tensile strength is in excess of 55 kg/mm² (34·9 ton/in²).

(e) For screw shafts intended for severe ice service, in addition to the tensile and bend tests, Charpy V-notch tests are to be taken from the test material at the propeller end of each shaft. The test pieces are to be cut in a longitudinal direction and the dimensions are to be in accordance with Q 2.

Mechanical Properties

606 (a) The tensile strength of steel forgings is to comply with the range specified in the order. With the

exception of screw shafts and propeller nuts the specified range for carbon and carbon-manganese steel forgings is not to exceed 10 kg/mm² (6·3 ton/in²) within the general limits of 44 and 70 kg/mm² (27·9 and 44·5 ton/in²).

When it is proposed to use a carbon or carbon-manganese steel of higher tensile strength full details are to be submitted for approval.

- (b) Screw shafts are, in general, to be restricted to a range of tensile strength between 44 and 52 kg/mm² (27·9 and 33 ton/in²).
- (c) Material for propeller nuts may be within the limits of 35 and 41 kg/mm² (22 · 2 to 26 ton/in²).
- (d) The percentage elongation is not to be less than the value given in Table Q 6.2 appropriate to the actual tensile strength of the steel.

Bend test pieces are to withstand being bent without fracture through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.3.

TABLE Q 6.2
Tensile Properties of Carbon Steel Forgings

Actual Tensile Strength		Elongation on 5,65 V So % minimum	
${ m kg/mm^2}$	ton/in ²	Longitudinal or in the Direction of Principal Grain Flow	Transverse or Across the Direction of Principal Grain Flow
35 to 40	22·2 to 25·4	27	22
Over 40 to 45	Over 25 · 4 to 28 · 6	25	21
,, 45 to 50	,, 28.6 to 31.8	23	19
,, 50 to 55	,, 31·8 to 34·9	22	18
" 55 to 60	,, 34·9 to 38·1	20	16
,, 60 to 65	,, 38·1 to 41·3	18	14
,, 65 to 70	,, 41·3 to 44·5	16	12
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TABLE Q 6.3

Bend Tests for Carbon Steel Forgings

Actual Tensile Strength		Maximum Internal Diameter of Bend or Diameter of Former	
		Longitudinal or in the Direction of	Transverse or Across the Direction
kg/mm ²	ton/in ²	Principal Grain Flow	of Principal Grain Flow
Up to 50	Up to 31.8	$-\frac{2}{3}t$	11t
Over 50 to 60	Over 31.8 to 38.1	t	2t
" 60 to 70	,, 38·1 to 44·5	2t	4t
		Where t=thickn ess of test piece	

Charpy V-notch tests from screw shafts intended for severe ice service are to be carried out at -10°C and are to give an average energy value of not less than 2,1 kg m (15 ft lb).

Inspection

- 607 (a) The Surveyor is to examine each forging before final acceptance at the forge.
- (b) Unless otherwise agreed, the forgemaster is to carry out an ultrasonic test on all forgings for shafts and other parts subject to significant fatigue loading, where the diameter or equivalent ruling section is 250 mm (10 in) or greater and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.
- (c) When small forgings are tested as a batch, the hardness of each forging is to be determined including those from which material is to be cut for the provision of tensile and bend test pieces. The hardnesses of the forgings are to comply with a specification approved by the Surveyor before manufacture of the forgings. The Surveyor is to satisfy himself that the inspection procedure for surface condition and soundness adopted by the manufacturer is adequate.

Repair of Defects

608 The repair of defects by welding is not permitted.

Identification

609 Forgings are to be identified in accordance with Q 109.

Documentation

610 The manufacturer is to supply the information detailed in Q 110 and a certificate of ultrasonic examination as required by 607(b).

CRANK SHAFT FORGINGS

Scope

611 Solid forged crank shafts and forgings for use in the construction of built or semi-built crank shafts are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

Manufacture

612 Forgings are to be manufactured in accordance with the requirements of 602.

For combined web and pin forgings the proposed method of forging is to be submitted for approval. It is recommended that these forgings be made by a folding method. Other methods which can be shown to produce sound forgings with satisfactory mechanical properties will be considered but where the gapping method is used for cranks having a pin diameter exceeding 510 mm (20 in) this will only be accepted provided that an upsetting operation is included in the manufacturing sequence. In general, the amount of work during the upsetting operation is to be such that the reduction in the original length of the ingot (after discard) or bloom is not less than 50 per cent.

Chemical Composition

613 The chemical composition is to be within the limits specified in 603 unless otherwise agreed.

Heat Treatment

614 Forgings are to be heat treated in accordance with the requirements of 604.

Test Material

615 Test material is to be provided on each forging as specified in 605. On slabs for crankwebs the test pieces are to be taken transversely.

Mechanical Properties

- 616 (a) The tensile strength is to comply with the range specified in the order. The specified range for carbon and carbon-manganese steel forgings is not to exceed 10 kg/mm² (6·3 ton/in²) within the general limits of 44 and 70 kg/mm² (27·9 and 44·5 ton/in²).
- (b) For crank webs and other parts where minimum yield stresses are specified the yield stress is not to be less than 50 per cent of the minimum specified tensile strength. (See H 206).
- (c) When it is proposed to use a steel of higher tensile strength full details, including yield stress, are to be submitted for approval.
- (d) The percentage elongation is not to be less than the value given in Table Q 6.2 appropriate to the actual tensile strength of the steel.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.3.

Inspection

- 617 (a) The Surveyor is to examine each forging before final acceptance at the forge.
- (b) The forgemaster is to carry out an ultrasonic test on all forgings for crank shafts which have finished pins or journals in excess of 250 mm (10 in) diameter and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.
- (c) Magnetic particle examination is to be carried out on the pins and journals of all solid forged crank shafts and

on the pin fillet of all combined web and pin forgings. This examination is to be carried out in the finished machined condition. Where forgings are supplied in the black or rough machined condition, this examination is to be carried out by the engine builder.

(d) When small forgings are tested as a batch, hardness tests, as detailed in 607(c), are to be carried out.

Repair of Defects

618 The repair of defects by welding is not permitted.

Identification

619 Forgings are to be identified in accordance with Q 109.

Documentation

620 The manufacturer is to supply the information detailed in Q 110 and a certificate of ultrasonic examination as required by 617(b).

FORGINGS FOR REDUCTION GEARING

Scope

621 Forgings for pinions, pinion sleeves, gear wheels and gear wheel rims intended for reduction gearing where the transmitted power exceeds 150 shp are to be manufactured and tested in accordance with the requirements of this section and the relevant parts of Q 1 and Q 2. Where the transmitted power is less than 150 shp the manufacturer's certificate of test may be accepted.

Forgings for flexible couplings, quill shafts and gear wheel shafts are to comply with 601 to 610.

Specifications for materials of pinions, pinion sleeves, wheel rims, gear wheels, flexible couplings and quill shafts giving chemical analysis, heat treatment and mechanical properties are to be submitted for approval with the plans of gearing, as required by G 104 and H 302.

When the teeth of a pinion or gear wheel are to be surface hardened, i.e., case hardened, nitrided or induction hardened, the proposed specification together with details of the process and practice are to be submitted for approval. In general, for nitrided gears the treatment time should not be less than 60 hours. Unless otherwise agreed the specified minimum tensile strength of the core is to be 80 kg/mm² (50·8 ton/in²) for induction hardened or nitrided gearing and 75 kg/mm² (47·6 ton/in²) for case hardened gearing (see H 307). For purposes of initial approval the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness and quality of the steel.

Manufacture

622 (a) Forgings are to be manufactured in accordance with the requirements of 602.

Sleeve forgings are to be hollow forged or hollow rolled where practicable.

Rim forgings are to be expanded by forging or rolling where practicable.

(b) All forgings are to be made with sufficient material to permit an adequate machining allowance on all surfaces for the removal of unsound or decarburised material. For alloy steel forgings the machining allowance on surfaces where teeth will be cut is to be not less than the following:—

Finished diameter of toothed portion	Machining Allowance
200 mm (8 in) or less	15 mm (0.6 in) on diameter
Over 200 mm (8 in)	25 mm (1·0 in) on diameter

Chemical Composition

623 Gear wheel and rim forgings with a specified minimum tensile strength not in excess of 75 kg/mm² (47.6 ton/in²) may be made in carbon or carbon-manganese steel complying with the following limits:—

Carbon	0,60% max.
Silicon	0,10% to 0,45%
Manganese	0,30% to 1,50%
Sulphur	0,040% max.
Phosphorus	0,040% max.

Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 75 kg/mm² (47·6 ton/in²) and all pinion or pinion sleeve forgings are to be made in a suitable alloy steel. Any of the following types of steel will be accepted:—

3% Ni
3½% Ni
1¾% Ni Cr Mo
2½% Ni Cr Mo
3% Ni Cr Mo
4½% Ni Cr Mo
1% Cr Mo
3% Cr Mo

Where it is proposed to use other steels the proposed chemical composition is to be submitted for approval.

Heat Treatment

624 (a) Forgings may be either normalized and tempered, oil hardened and tempered or water hardened and tempered in accordance with the approved specification. The tempering temperature is not to be less than 550°C.

At the discretion of the manufacturer, heat treatment may be carried out either in the black "as forged" condition or after rough machining. It is recommended, however, that where the finished diameter of the toothed portion exceeds 200 mm (8 in), forgings should be rough machined prior to hardening and tempering.

Where forgings are machined prior to heat treatment, the allowance left for final machining is to be sufficient to remove the decarburized surface material taking into account any bending or distortion which may occur.

- (b) Where induction hardening or nitriding is to be carried out after machining of the gear teeth the forgings are to be heat treated at an appropriate stage to a condition suitable for the subsequent surface hardening.
- (c) Forgings for gears which are to be case hardened after final machining are to be supplied in a condition suitable for subsequent machining and case hardening.

Test Material

Through hardened, induction hardened or nitrided gear forgings.

- 625 (a) At least one tensile and one bend test piece are to be taken from each forging in carbon or carbon-manganese steel and at least one tensile and one set of impact tests when the forgings are to be made in alloy steel. Sufficient test material is to be provided for this purpose and the test pieces are to be taken as follows:—
 - (i) Where the finished diameter over the portion where teeth will be cut is 200 mm (8 in) or less, the test pieces are to be cut in a longitudinal direction from the end of the forging (see Fig. Q 6.1).
 - (ii) Where the above finished diameter exceeds 200 mm (8 in) the test pieces are to be cut in a transverse or circumferential direction adjacent to the position where the teeth will be cut (see Fig. Q 6.2). In the case of forgings where the diameter of the journal precludes the preparation of test pieces from this position, test material may be provided on the ends of the journals. Where the finished journal diameter is 200 mm (8 in) or less these test pieces are to be cut in a longitudinal direction. Where the finished journal diameter exceeds 200 mm (8 in) the test pieces are to be cut in a transverse direction (see Fig. Q 6.3).
 - (iii) When the finished length of a pinion forging, excluding the journals, exceeds 1,25 m (4 ft) tests as prescribed in (ii) are required from each end.
 - (iv) When the finished diameter of a gear wheel or rim exceeds 2,5 m (8 ft) or the weight (as forged) exceeds 3000 kg (3 tons), two sets of tests are to

- be taken from positions diametrically opposed and for gear rim forgings from opposite ends when the width of the face on which teeth will be cut exceeds 1000 mm (39.4 in) (see Fig. Q 6.4).
- (b) When a forging is subsequently divided into a number of items all of which are heat treated together in the same furnace then for test purposes this may be considered as one forging and the test material required is to be related to the total length and weight of the original forging.

Where a number of separate forgings are made from one cast of steel and heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

(c) The dimensions of the tensile test pieces are to comply with Q 2 and they are to have a diameter of not less than 14 mm (0.564 in) except where the dimensions of the forging will not permit this diameter of test piece being prepared. In such cases the test piece is to be of the largest practicable diameter.

Bend test pieces are to be machined in accordance with Q 2 the subsidiary test piece (20 mm by 10 mm) being used when the specified minimum tensile strength is in excess of 55 kg/mm² (34·9 ton/in²).

Impact test pieces are to be machined in accordance with Q 2 and may be of either the Izod, Charpy V-notch or Charpy U-notch types.

Case hardened gear forgings

(d) Sufficient material for test purposes both at the forgemaster's and manufacturer's works is to be provided generally as specified in (a) and (b) except that, irrespective of the dimensions or weight of the forging, tests are required from one position only and in the case of forgings with integral journals are to be cut in a longitudinal direction.

A sufficient number of test blocks with a cross-section of 63 mm (2.5 in) diameter and of suitable length are to be machined from the test material for use at the forge and gear manufacturer's works.

For small forgings where a system of batch testing is adopted, the test blocks may be machined from test material made from surplus steel from the same cast provided that the forging reduction approximates to that of the actual gear forgings.

Tensile and impact tests are to be taken by the forgemaster from test blocks which have been given a blank carburising and heat treatment cycle simulating that which will be subsequently applied to the forgings. These test pieces are to be prepared in accordance with (c) and are to be cut with their axis at about 12,5 mm (0.5 in) from the surface of the test block. A similar set of mechanical tests are also to be taken at the gear manufacturer's works from test blocks which have been blank carburized and heat treated with the gear forgings they represent.

At the discretion of the manufacturer test blocks of larger cross-section may be blank carburized but these are then to be machined to 63 mm (2.5 in) diameter prior to the final hardening and tempering heat treatment.

Where it is proposed to adopt alternatives to the foregoing full details are to be submitted for consideration.

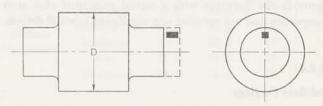
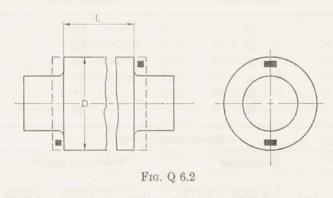
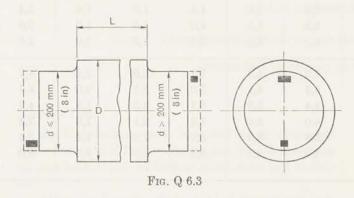


Fig. Q 6.1

Diameter D 200 mm (8 in) or less

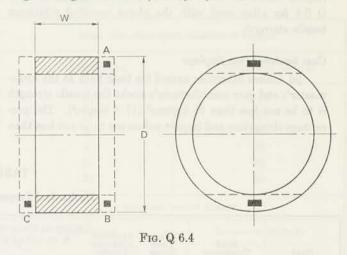


Diameter D greater than 200 mm (8 in). Two sets of test pieces are required only when length L is greater than 1,25 m (4 ft).



Diameter D greater than 200 mm (8 in) but journal diameter precludes tests as shown in Fig. Q 6.2. When journal diameter C is 200 mm (8 in) or less, tests to be cut

in longitudinal direction. When journal diameter d is greater than 200 mm (8 in) tests to be cut in transverse direction. Two sets of test pieces are required only when length L is greater than 1,25 m (4 ft).



Two sets of test pieces are required only when the diameter D is greater than 2,5 m (8 ft) or weight greater than 3000 kg (3 tons).

When the width W is 1000 mm (39.4 in) or less tests may be taken from positions A and B. When W exceeds 1000 mm (39.4 in) tests are to be taken from positions A and C.

Mechanical Properties

Through hardened gear forgings

626 (a) The tensile strength is to be within the range specified in the order. The specified range is not to exceed 10 kg/mm² (6·3 ton/in²). These ranges are to be within the general limits of 60 and 120 kg/mm² (38·1 and 76·2 ton/in²) for pinions or 45 and 100 kg/mm² (28·6 and 63·5 ton/in²) for gear wheels. Consideration is also to be given to maintaining the necessary hardness differential between pinion and gear wheel teeth (see H 303).

The percentage elongation is not to be less than the value given in Table Q 6.4 appropriate to the specified minimum tensile strength of the steel.

Bend test pieces from carbon and carbon-manganese steel forgings are to withstand being bent through 180° round a former having a diameter not greater than that specified in Table Q 6.4.

The impact tests from alloy steel forgings are to be made at room temperature and are to give energy values not less than the appropriate value given in Table Q 6.4.

Proposals to use materials of higher tensile strength are to be submitted for approval.

Induction hardened and nitrided gear forgings

(b) The tensile strength is to be not less than 80 kg/mm^2 (50.8 ton/in^2) and the percentage elongation and impact values are to be not less than those given in Table Q 6.4 for alloy steel with the above specified minimum tensile strength.

Case hardened gear forgings

(c) Unless otherwise agreed for tests both at the forge-master's and gear manufacturer's works the tensile strength is to be not less than 75 kg/mm² (47.6 ton/in²). The percentage elongation and impact values are to be not less than

the values appropriate to the actual tensile strength as given in Table Q 6.4 for oil hardened and tempered alloy steels.

Inspection

627 (a) The Surveyor is to examine each forging before acceptance at the forge.

(b) The forgemaster is to carry out an ultrasonic examination of all forgings where the finished diameter of the toothed portion is in excess of 200 mm (8 in), and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

TABLE Q 6.4

Mechanical Properties of Gear Forgings

	Heat	Minimum Yield	Specified Minimum		Elongation ,65 V So		Bend Tes	t—Maximum l	Diameter of	Former		
Steel	Treatment	Stress kg/mm ²	Tensile Strength kg/mm ²	Longl.	Transv. (Note 1)	Longitudinal			Transverse (Note 1)			
HEAT TOLEY	Normalized	23	45	23	19	0766	2 t	an plant	$1\frac{1}{3}$ t			
G-1	and Tem-	25	50	22	18		2 t			11t		
Carbon or	pered or Oil	28	55	20	16		t			2t		
Carbon-	hardened	30	60	18	14		t		2t			
Manganese	and	33	65	17	12	2t				4t		
	Tempered	35	70	16	11		2t		4t			
7-11-2			>-			Minimum Impa Longitudinal			act Energy			
	A 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	W							Tre	ansverse (No	te 1)	
header of a			rai/her	ulla mi be		Izod kg m	Charpy V-notch kg m	Charpy U-notch kg m/cm ²	Izod kg m	Charpy V-notch kg m	Charpy U-notch kg m/cm	
Parpai II	Normalized	33	60	18	14	. 2,8	2,2	4.7	2,1	1,7	3,8	
	and	38	70	17	13	2,5	2,0	4,4	1,8	1,4	3,4	
Alloy	Tempered	43	80	15	12	2,2	1,8	4,0	1,5	1,2	3,0	
		48	90	13	11	1,9	1,5	3,6	1,2	1,0	2,6	
Indiana a		42	60	18	14	4,9	4,2	7,1	2,8	2,2	4,7	
	Oil	47	70	17	13	4,7	4,1	7,0	2,5	2,0	4,4	
411	hardened	60	80	15	12	4,4	3,8	6,7	2,3	1,9	4,2	
Alloy	and	70	90	13	10	4,0	3,4	6,2	2,1	1,6	3,8	
	Tempered	80	100	12	8	3,6	3,0	5,7	1,8	1,4	3,4	
-	-70	90	110	11	7	3,0	2,5	5,1	1,5	1,2	3,0	

t = thickness of the test piece

Note 1. Circumferential test pieces from rim forgings are to give longitudinal properties.

Intermediate values may be obtained by interpolation.

or in British units:-

TABLE Q 6.4

Mechanical Properties of Gear Forgings

04- X	Heat	Minimum Yield	Specified Minimum		Elongation 65 V So	hander Land	Bend Te	est—Maximur	m Diameter	of Former			
Steel	Treatment	Stress ton/in ²	Tensile Strength ton/in ²	Longl.	Transv. (Note 1)	Longitudinal		nal	Transverse (Note 1)				
	Normalized	14.6	28.6	23	19		2t		1 ₃ t				
Carbon or	and Tem-	15.9	31.8	22	18		2t	W. L. COLL	111t				
Carbon or	pered or Oil	17.8	34.9	20	16		t			2t			
	hardened	19.1	38.1	18	14		t		2t				
Manganese	and	21.0	41.2	17	12	2t 2t Minimum I			4t				
	Tempered	22.0	44.4	16	11				4t				
									mpact Ener	gy			
					hald.		Longitudina		Tr	ansverse (Not	e 1)		
						Izod	Charpy V-notch	Charpy U-notch	Izod	Charpy V-notch	Charpy U-note		
					1.0	ft lb	ft lb	ft lb	ft 1b	ft lb	ft 1b		
	Normalized	21.0	38 · 1	18	14	20	16	17	15	12	14		
Alloy	and	24.1	44.4	17	13	18	15	16	13	10	12		
Alloy	Tempered	27.3	50.8	15	12	16	13	14	11	9	11		
		30.5	57.2	13	11	14	11	13	9	7	9		
Trulis.		26.7	38 · 1	18	14	35	31	26	20	16	17		
	Oil	29.8	44.4	17	13	34	30	25	18	15	16		
Alloy	hardened	38 · 1	50.8	15	12	32	28	24	17	14	15		
	and	44.4	57.2	13	10	29	25	22	15	12	14		
	Tempered	50.8	63.5	12	8	26	22	21	13	10	12		
		57.2	69.9	11	7	22	18	18	11	9	11		

t = thickness of the test piece

Note 1. Circumferential test pieces from rim forgings are to give longitudinal properties.

Intermediate values may be obtained by interpolation.

Hardness Tests

(c) Hardness tests are to be carried out on all forgings after completion of heat treatment and prior to machining the gear teeth, except on forgings intended for case hardening.

When the diameter of the finished item is less than 500 mm (19.7 in) one hardness test is to be made on each forging.

When the diameter of the finished item exceeds 500 mm

 $(19 \cdot 7 \text{ in})$ at least two hardness tests are to be made on each forging at positions diametrically opposite on the portion where the teeth will be cut. When the length of this portion exceeds $500 \text{ mm} (19 \cdot 7 \text{ in})$ two tests are to be made at each end.

When the diameter of the finished item is 1000 mm (39·4 in) or more, at least four hardness tests are to be made. These tests are to be spaced at equal distances round the circumference and this distance is not to exceed 1000 mm

(39.4 in). When the width of the face on which the teeth will be cut exceeds 500 mm (19.7 in) tests are to be made at each end.

- (d) The difference between the highest and lowest value is not to exceed the equivalent of 20 Brinell numbers when the minimum specified tensile strength does not exceed 60 kg/mm² (38 ton/in²) or 30 Brinell numbers when the minimum specified tensile strength is more than 60 kg/mm² (38 ton/in²).
- (e) On case hardened, nitrided or induction hardened components hardness tests are to be made on the teeth when surface hardening and grinding has been completed. The results are to comply with the approved values.

Sulphur Prints

(f) On forgings with integral journals and on pinion sleeves sulphur prints are to be taken over the whole surface and ends of the toothed portion.

On forgings for gear wheels and rims sulphur prints are to be taken from one of the end faces. At the discretion of the Surveyor additional prints may be requested from selected areas on the exterior surface.

When a system of batch testing is being employed the number of sulphur prints to be taken from each batch is to be agreed.

Magnetic Crack Detection

(g) The teeth of all components which have been case hardened, nitrided or induction hardened are to be examined by magnetic particle methods. This may be requested as a supplementary test on other items.

When current flow methods are used for magnetization, particular care must be taken to avoid damaging the hardened surfaces by contact with the probes.

Depth of Hardened Zone

(h) On gear forgings where the teeth have been case hardened, nitrided or induction hardened additional test pieces may require to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor and for induction or case hardened gearing the depth of the hardened zone is to be in accordance with the approved specification or as otherwise agreed. For nitrided gearing the full depth of the hardened zone, i.e., depth to core hardness, is not to be less than 0,5 mm (0.020 in) and the hardness at a depth of 0,25 mm (0.010 in) is not to be less than 500 D.P.N. See 621.

Repair of Defects

628 The repair of defects by welding is not permitted.

Identification

629 Forgings are to be identified in accordance with Q 109.

Documentation

630 The manufacturer is to supply the information detailed in Q 110.

FERRITIC STEEL FORGINGS FOR TURBINES, COMPRESSORS AND TURBINE DRIVEN GENERATORS

Scope

631 Ferritic steel forgings for turbine rotors, discs and spindles, turbine driven generator rotors and compressor rotors are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

Orders and drawings for rotor forgings are to state whether the rotor is intended for propulsion or auxiliary machinery and the shaft horse power of auxiliary turbines. In the case of a rotor which is to be tested for thermal stability the maximum operating temperature and the proposed test temperature are also to be stated.

Where small and identical forgings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the firm.

Manufacture

632 Forgings are to be manufactured in accordance with the requirements of 602 except that for rotor forgings the sectional area of any part (as forged) is not to exceed one half of the average sectional area of the ingot. Where an upsetting operation is included in the manufacturing procedure the above requirement is to apply to the sectional area of the upset bloom and not to the ingot.

Chemical Composition

633 The forgings may be made of carbon or alloy steel. For forgings in carbon steel the chemical composition is to comply with the following:—

 Carbon
 0,45% max.

 Silicon
 0,15 to 0,45%

 Manganese
 0,40% min.

 Sulphur
 0,050% max.

 Phosphorus
 0,050% max.

Where mechanical tests are required from forgings in either the radial or the tangential direction the sulphur and the phosphorus contents of the steel are not to exceed 0,040 per cent each.

Specifications of alloy steel forgings giving the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans of the components.

When it is proposed to use rotors of welded construction the compositions of the steels for the forgings are to be submitted for special consideration. These are to comply with the above limits of composition except that generally the carbon content is not to exceed 0,25 per cent.

Heat Treatment

634 Forgings are to be supplied in the heat treated condition and the thermal treatment at all stages is to be such as to avoid the formation of hair-line cracks. At a suitable stage of manufacture the forgings are to be reheated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

Where forgings receive their main heat treatment before machining they are to be stress relieved after rough machining. Forgings heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

The tempering and stress relieving temperatures are to be not less than 550°C in the case of carbon steels and 600°C in the case of alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

If forgings are stress relieved after the mechanical tests have been taken the temperature used for this treatment is to be at least 20degC lower than the temperature previously used for tempering and the forgings are subsequently to be cooled at approximately the same rate as was used for cooling after tempering.

Details of the proposed heat treatment for rotors of welded construction are to be submitted for approval.

Test Material

635 At least one longitudinal tensile and one bend test piece are to be taken to represent the material of each forging (or multiple forging) excluding discs. In the case of forgings (or multiple forgings) exceeding both 3000 kg (3 tons) in weight and 2 m (6.5 ft) in length not less than one tensile and one cold bend test are to be taken from each end of each forging (or multiple forging) (see Fig. Q 6.5).

For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1500 shp tangential and, where dimensions permit, radial tensile and bend tests are also to be taken from the end of the body corresponding to the top end of the ingot (see Fig. Q 6.5).

For each turbine disc, at least one tensile and one bend test piece are to be cut in a tangential direction from material at the hub (see Fig. Q 6.6).

For this purpose, sufficient test material is to be left on each forging and is not to be removed until heat treatment has been completed except for stress relieving after rough machining as detailed in 634. In this connection a thermal stability test does not form part of the heat treatment of a turbine forging. Any excess test material is not to be completely severed from a forging until all the mechanical tests have been completed with satisfactory results.

Where a number of small forgings are made from one cast of steel and heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

The dimensions of the tensile test pieces are to comply with Q 2 and they are to have a diameter of not less than 14 mm (0.564 in) except that if necessary the tangential and radial test pieces may be of smaller diameter, in all cases these should be as large as possible and of standard proportions.

Bend test pieces are to be machined to 20 mm by 10 mm in accordance with the subsidiary test piece defined in Q 206.

Top end of ingot

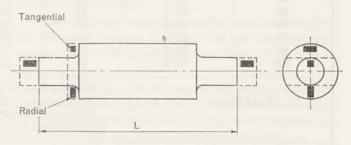


Fig. Q 6.5 Rotor Forgings

Two sets of longitudinal test pieces are required only when the length L exceeds 2 m (6.5 ft) and the weight exceeds 3000 kg (3 tons). Tangential and, where dimensions permit, radial test pieces from the body are required from rotor forgings for main propulsion machinery and for auxiliary turbines exceeding 1500 shp.

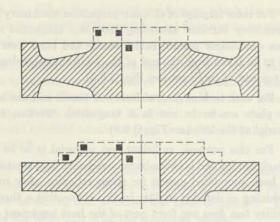


Fig. Q 6.6 Turbine Discs

Alternative positions for test pieces.

Mechanical Properties

636 The tensile strength of the forging is to comply with the range specified on the order. For carbon and carbon-manganese steel forgings the specified range of tensile strength is not to exceed 10 kg/mm² (6·3 ton/in²)

within the general limits of 45 and 70 kg/mm² (28·6 and 44·5 ton/in²). For alloy steel rotor forgings the specified range is not to exceed 15 kg/mm² (9·5 ton/in²) within the general limits of 45 and 95 kg/mm² (28·6 and 60·3 ton/in²). For discs and other alloy steel forgings the specified range is not to exceed 15 kg/mm² (9·5 ton/in²) within the general limits of 45 and 115 kg/mm² (28·6 and 73 ton/in²).

When it is proposed to use a steel of higher tensile strength full details are to be submitted for approval.

The yield stress, percentage elongation and percentage reduction of area are to comply with the requirements of Table Q 6.5 appropriate to the specified minimum tensile strength of the steel.

The minimum angles and maximum diameters of formers for the bend tests are given in Table Q 6.5.

Inspection

637 (a) The Surveyor is to examine each forging before final acceptance at the forge.

(b) The forgemaster is to carry out an ultrasonic test on each forging and is to provide the Surveyor with a signed

TABLE Q 6.5

Mechanical Properties of Ferritic Steel Forgings for Turbines, Compressors and Generators

Specified Minimus	m Tensile Strength		rcentage Elongat		Maximum diameter of former for bend tes						
Specifica Million	III Totalio Strongui	10	ength of 5,65 V	io	180°	150°	120°				
kg/mm ²	ton/in2	Long.	Tan.	Rad,	Long.	Tan.	Rad.				
45	28.6	24	20	17	2t	2t	2t				
50	31.8	23	19	16	2t	2t	2t				
55	34.9	22	17	15	2 ² / ₃ t	2 ² / ₃ t	2%t				
60	38.1	19	16 .	14	4t	4t	23t 4t				
70	44.5	17	14	12	4t	4t	4t				
80	50.8	16	12	10	4t	4t					
90	57.2	15	11	_	6t	6t	-				
100	63.5	14	10	-	6t	6t	1				
Yield Stress		Not less than 50% of the actual tensile strength for material in the normalized and tempered condition. Not less than 60% of the actual tensile strength for low alloy material in the quenched and tempered condition.									
Reduction of area		Not less than 35% for longitudinal tests. Not less than 30% for tangential tests. Not less than 20% for radial tests.									

Long. — For longitudinal tests
Tan. — For tangential tests
Rad. — For radial tests
t — Thickness of test piece.

Intermediate values are to be obtained by interpolation.

statement that such inspection has not revealed any significant internal defects.

(c) The end faces of the body of rotor forgings are to be machined to a fine smooth finish for visual and magnetic particle examination.

The end faces of the boss and the bore surface of each turbine disc are to be machined to a smooth finish and examined by a suitable method of magnetic crack detection.

(d) Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1500 shp are to be hollow bored for internal examination. The surface of the bore is to have a fine smooth finish and it is to be examined by means of an optical instrument of suitable magnification. Where the bore size permits, magnetic particle examination is also to be carried out. These examinations are to be confirmed by the Surveyor. Alternatively, an approved method of ultrasonic examination may be accepted instead of hollow boring. Details of the proposed method of ultrasonic examination are to be submitted for special consideration.

Thermal Stability Test

- (e) Thermal stability tests after heat treatment and rough machining of the turbine rotors referred to in H 807 are to be undertaken in properly constructed furnaces, using accurate and reliable measuring equipment. Each test is to be carried out in accordance with the following recommended procedure:—
 - (i) Five bands are to be machined concentric with the axis of rotation. Two of these are to be reference bands and are to be positioned at or near the locations of the bearings. The remaining three bands are to be test bands located one as near as possible to the midlength, and the other two near each end of the body. Where the length of a rotor is such that five bands cannot be provided, alternative proposals are to be submitted to the Surveyor for his approval.
 - (ii) Four positions, 90° apart, are to be stamped A, B, C and D, on the coupling end of the rotor.
 - (iii) The whole of the body and as much of the shaft at either end as will include the positions of the glands are to be enclosed in the furnace. In the case of a rotor having an overhung astern wheel, the astern wheel is also to be enclosed in the furnace during the first test (see H 807).
 - (iv) The rotor is to be rotated at a uniform and very slow speed.

- (v) The deflections at all bands are to be recorded at the A, B, C and D positions. Initial cold readings are to be taken prior to heating.
- (vi) The rotor is to be heated uniformly and slowly. Temperatures are to be recorded continuously at the surface of the rotor and if practicable in the bore at the mid-length of the body. Under no circumstances is the surface temperature to exceed the temperature at which the rotor was tempered. During heating the rate of rise of temperature is to be such as to avoid excessive temperature gradients in the rotor.
- (vii) The maximum or holding temperature is to be not less than 28degC (50degF) above the maximum operating temperature of the rotor. For the purposes of the test the holding period is to start when the rotor has attained a uniform and specified temperature. The rotor is to be held under the specified temperature conditions until not less than three consecutive hourly readings of deflections show the radial eccentricity to be constant within 0,006 mm (0⋅00025 in) on all test bands.
- (viii) The turbine rotor is to be rotated during cooling until the temperature is not more than 100°C (212°F). The rate of cooling is to be such as to avoid excessive temperature gradients in the rotor.
 - (ix) Final cold readings are to be taken.

The movements of the axis of the rotor in relation to the reference bands are to be determined from polar plots of the deflection readings.

The radial movement of the shaft axis as determined by the difference between the final hot and the final cold movements is not to exceed 0,025 mm (0.001 in) on any one hand.

As verification that test equipment and conditions are satisfactory it is required that similar determinations of differences between initial cold and final cold movements do not exceed 0,025 mm (0.001 in) on any one band.

If the results of the test on a rotor fail to meet either or both of the above requirements, the test may be repeated if requested by the maker and agreed by the Surveyor.

In the case of a rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor are to be submitted for special consideration.

Repair of Defects

638 The repair of defects by welding is not permitted.

Identification

639 Forgings are to be identified in accordance with Q 109.

Documentation

640 The manufacturer is to supply the information detailed in Q 110 and a certificate of ultrasonic examination as required by 637(b).

FORGINGS FOR BOILERS AND PRESSURE VESSELS

Scope

641 Forged seamless drums, headers and other forgings intended for boilers and pressure vessels are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2. For pressure vessels containing radio-active materials or gases additional requirements may be specified.

Provision is made for three categories of forgings which differ mainly in respect of testing procedure and are intended for the following uses:—

Category I Where design is based on guaranteed values for elevated temperature properties.

Category II Where design is based on nominal values for elevated temperature properties which are not required to be proved by tests.

Category III For pressure vessels intended for special low temperature service where the steel is to have guaranteed low temperature Charpy V-notch impact properties. In this case the proposed specification is to be submitted for approval.

Alternative specifications may be accepted provided they give reasonable equivalents to the requirements of this Section.

Where small and identical forgings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the manufacturer.

Manufacture

642 Forgings are to be manufactured in accordance with the requirements of 602.

Seamless drums and headers are to be forged from ingots or forged blooms which have been punched, bored or trepanned. Alternatively, where specially approved, hollow cast ingots may be used. The wall of the hollow ingot or bloom is to be reduced in thickness by at least two-thirds during subsequent forgings. Other proposals are to be submitted for approval.

Chemical Composition

643 For Categories I or II the chemical composition of the steel is to comply with the requirements of Table Q 3.1 except that the steel is to be killed.

For Category III the chemical composition is to comply with the requirements of the approved specification.

Heat Treatment

644 All carbon and carbon-manganese steel forgings are to be normalized or normalized and tempered. All alloy steel forgings are to be normalized and tempered.

If required by the Surveyors or by the fabricators test material may be given a simulated stress relieving heat treatment prior to the preparation of the test pieces. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties, which can be expected.

Test Material

645 (a) Category I. Tensile and bend tests are to be made at ambient temperature on material from each forging.

On seamless drums and headers, which are initially forged with open ends, test material is to be provided at each end of each forging. On seamless drums or headers, forged with one solid end, test material is to be provided at the open end only. Except where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed. Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. In all cases the test pieces are to be cut in a circumferential direction.

In addition to the tests at ambient temperature, one tensile test at elevated temperature is to be made to represent each drum or header forging. This test piece is to be taken from the end which gave the lower tensile value at ambient temperature.

For forgings other than seamless drums and headers test material is to be provided for tensile and bend tests at ambient temperature in accordance with 605. In addition, one tensile test at elevated temperature is to be made from each forging or for each batch of forgings. Tensile tests at elevated temperature are not required when:—

- (i) the reference test temperature is 100°C or less,
- (ii) the specified minimum value of the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value,
- (iii) the actual tensile strength at ambient temperature exceeds by at least 4 kg/mm² (2·5 ton/in²) the minimum specified tensile strength. This applies only to carbon and carbon-manganese steels.
- (b) Category II. Test material is to be provided for the tests at ambient temperature specified for Category I. Tests at elevated temperatures are not required.
- (c) Category III. On seamless drums and headers test material is to be provided for the tests at ambient temperature specified for Category I. In addition, three Charpy V-notch test pieces are to be prepared from each end except for drums or headers forged with one solid end, when impact tests are required from the open end only.

For forgings other than seamless drums and headers test material is to be provided for the tests at ambient temperature specified for Category I and, in addition, Charpy V-notch test pieces are to be taken from each forging or from each batch of forgings when specified.

(d) The dimensions of the tensile test pieces are to comply with the requirements of Q 2. Test pieces for ambient temperature tests are to have a diameter of not less than 14 mm (0.564 in) unless the thickness of the test material is insufficient, in which case the diameter is to be as large as possible.

Bend test pieces are to be in accordance with Q 2.

Charpy V-notch test pieces are to be machined in accordance with the dimensions given in Q 2.

Mechanical Tests

646 (a) Category I. The results of all tensile tests are to comply with the values given in Table Q 6.6. The lower yield or 0,2 per cent proof stress values at elevated temperatures are to be determined at the reference test temperature given in the order and are to comply with the values given in the above Table or as otherwise agreed with the manufacturer.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.6.

Stress rupture values for design purposes are given in Table Q 3.5.

(b) Category II. The results of all tensile tests at ambient temperature are to comply with the values given in Table Q 6.7.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.7.

For design purposes nominal values of the lower yield or 0,2 per cent proof stress at elevated temperatures are given in Table Q 6.7 and stress rupture values in Table Q 3.5.

(c) Category III. The results of all tensile, bend and impact tests are to comply with the approved specification. The Charpy V-notch tests are to be made at or below the approved reference test temperature.

Inspection

647 The Surveyor is to examine each forging before final acceptance at the forge.

On seamless drums sulphur prints may be requested to demonstrate that sufficient ingot discard has been taken.

When a number of separate small forgings are tested as a batch, the hardness of each forging is to be determined including those from which material is to be cut for the provision of tensile, bend and Charpy test pieces. The hardness of the forgings are to comply with a specification approved by the Surveyor before manufacture of the forgings. The Surveyor is to satisfy himself that the inspection procedure for surface condition and soundness adopted by the manufacturer is adequate.

Repair of Defects

648 The repair of minor surface defects in accordance with Q 108 will be considered.

Identification

649 Forgings are to be identified in accordance with Q 109.

Documentation

650 The manufacturer is to supply the information detailed in Q 110.

Chapter Q

TABLE Q 6.6

Mechanical Properties of Forgings for Boilers and Pressure Vessels Category I

	Yield Stress	Tensile	Elonga- tion on	Bend Test				Minimum	Lower Yie	eld or 0,2 %	6 Proof St	ress, kg/n	m ²		
Frade of Steel Stress Minimum kg/mm ² Strength kg/mm ²	Strength kg/mm ²	5,65 \sqrt{So} % Mini- mum	Maximum diameter of former	100°C	150°C	200°C	250°C	306°C	350°C	400°C	450°C	500°C	550°C	600°C	
Carbon	18,4	37-47	25	2t	16,7	15,7	14,6	13,9	12,9	12,1	11,3	10,9			1
and	20,9	42-52	23	2t	19,2	18,3	17,2	16,4	15,4	14,6	13,9	13,4			
Carbon-	23,5	47-57	21	3t	21,7	20,8	19,7	18,9	17,9	17,2	16,4	15,9			-,
Manganese	26,0	52-62	20	3t	24,3	23,3	22,2	21,4	20,5	19,7	18,9	18,4			
1Cr−½Mo	23,6	42–52	23	3t	22,8	22,0	21,3	19,1	16,7	15,1	14,8	14,5	14,2		
2½Cr-1Mo	39,4	55-68	18	3t	36,1	34,5	33,7	33,2	32,9	32,6	32,0	30,3	27,5	22,0	

t = thickness of bend test piece.

TABLE Q 6.6

Mechanical Properties of Forgings for Boilers and Pressure Vessels Category I

Grade of Steel	Yield Stress Minimum	Tensile	Elonga- tion	Bend Test			1	dinimum l	Lower Yie	ld or 0.29	6 Proof St	ress— ton lb/i	/in² n²		
Grade of Steel	Minimum ton/in ²	Strength ton/in ²	5.65 V So % Mini- mum	Maximum diameter of former	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°
To the	11.7	23 · 5 – 29 · 8	25	2t	10·6 23 700	10·0 22 400	9·3 20 800	8·8 19 700	8·2 18 400	7·7 17 200	7·2 16 100	6·9 15 500	av.		
Carbon	13.3	26 · 7-33 · 0	23	2t	12·2 27 300	11·6 26 000	10·9 24 400	10·4 23 300	9·8 22 000	9·3 20 800	8·8 19 700	8·5 19 000			
Carbon- Manganese	14.9	29 · 8 – 36 · 2	21	3t	13·8 30 900	13·2 29 600	12·5 28 000	12·0 26 900	11·4 25 500	10·9 24 400	10·4 23 300	10·1 22 600			
	16.5	33 · 0 – 39 · 4	20	3t	15·4 34 500	14·8 33 200	14·1 31 600	13·6 30 500	13·0 29 100	12·5 28 000	12·0 26 900	11·7 26 700			
1Cr−½Mo	15.0	26 · 7-33 · 0	23	3t	14·5 32 400	14·0 31 300	13·5 30 200	12·1 27 100	10·6 23 800	9·6 21 500	9·4 21 100	9·2 20 600	9·0 20 200		
2½Cr-1Mo	25.0	34 · 9-43 · 2	18	3t	22·9 51 300	21·9 49 100	21·4 47 900	21·1 47 300	20·9 46 800	20·7 46 400	20·3 45 500	19·2 43 000	17·5 39 200	14·0 31 400	

t = thickness of bend test piece

Table Q 6.6

MATERIALS FOR BOILERS, PRESSURE VESSELS AND MACHINERY

TABLE Q 6.7

Mechanical Properties of Forgings for Boilers and Pressure Vessels Category II

Grade of Steel	Yield Stress Minimum	ield Tensile tion o	Elonga- tion on	tion on	tion on	tion on	tion on	Bend Test Maximum	7	21.00	10.13	Lower Yie	ld or 0,2%	% Proof St	ress, kg/m	m² (Note	1)		
Grade of Steel	Grade of Steel Minimum kg/mm ² Strength kg/mm ²	% Mini- mum	diameter of former	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C					
Carbon	18,4	37-47	25	2t	14,8	14,5	14,2	12,8	11,2	9,6	9,4	9,4		24					
and	20,9	42-52	23	2t	18,0	17,6	17,3	15,8	14,2	12,6	12,3	12,0							
Carbon-	23,5	47-57	21 .	3t	21,0	20,8	20,3	18,6	17,0	15,4	14,5	13,5							
Manganese	26,0	52-62	20	3t	24,1	23,8	23,1	21,4	19,9	18,3	16,5	15,0							
1Cr−½Mo	23,6	42-52	23	3t	19,5	18,7	18,1	16,2	14,2	12,8	12,6	12,3	12,1						
2½Cr-1Mo	39,4	55-68	18	3t	30,7	29,3	28,6	28,2	27,9	27,7	27,2	25,7	23,4	18,7					

t = thickness of bend test piece

Note 1. The values for yield stress or 0,2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by test.

or in British units:-

TABLE Q 6.7

Mechanical Properties of Forgings for Boilers and Pressure Vessels Category II

Grade of Steel	Yield Stress	Tensile	Elonga- tion on	Bend Test Maximum			1	Lower Yie	ld or 0 · 2 9	% Proof S	tress, lb/in	1 ² (Note 1)		
Grade of Steel	Frade of Steel Minimum ton/in2 Strength ton/in2	Strength ton/in ²	5.65 V So % Mini- mum	diameter of former	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	6uo°C
Carbon	11.7	23 - 5 - 29 - 8	25	2t	21 100	20 600	20 200	18 200	15 900	13 700	13 400	13 400			
and	13.3	26 · 7-33 · 0	23	2t	25 600	25 000	24 600	22 500	20 200	17 900	17 500	17 100			
Carbon-	14.9	29 - 8-36 - 2	21	3t	29 900	29 600	28 900	26 500	24 200	21 900	20 600	19 200			
Manganese	16.5	33 • 0 – 39 • 4	20	3t	34 300	33 900	32 900	30 400	28 300	26 000	23 500	21 300			
1Cr−½Mo	15.0	26 · 7 – 33 · 0	23	3t	27 700	26 600	25 700	23 000	20 200	18 200	17 900	17 500	17 200		
2½Cr-1Mo	25.0	34 · 9 – 43 · 2	18	3t	43 600	41 700	40 700	40 200	39 800	39 400	38 700	36 600	33 300	26 700	

t = thickness of bend test piece.

Note 1. The values for yield stress or 0.2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by test.

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Section 7

STEEL TUBES AND PIPES

Scope

701 (a) Boiler tubes, superheater tubes and pipes intended for use in the construction of boilers and pressure vessels are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q1 and Q2. These requirements are also applicable to pressure pipes intended for the services detailed in E 508 and for special low temperature service. Pressure pipes other than those mentioned in E 508 and having a design pressure of not less than 7 kg/cm² (100 lb/in²) may be made and tested to the requirements of this Section, or alternatively, may be in accordance with an approved national specification except that forge butt welded pipes are not acceptable. (See E 508, quoted at end of this Section).

Pressure pipes, when available in suitable sizes, may be used for the manufacture of seamless pressure vessels or headers and in such cases the requirements for forgings given in Q 643 to Q 650 would be applicable.

Provision is made for four categories which differ mainly in respect of testing procedures and are intended for the following uses:—

Category I Where design is based on guaranteed values for elevated temperature properties.

Category II Where design is based on nominal values for elevated temperature properties which are not required to be proved by test.

Category III(a) For special low temperature service where the steel is required to have guaranteed low temperature Charpy V-notch impact properties. This category is not applicable to material with a thickness under 3 mm (0·12 in).

Category III(b) For similar service where fine grain steels are acceptable without proving the low temperature impact properties by acceptance tests.

For Category III(a) and III(b) material, the proposed specification is to be submitted for approval.

(b) Orders should indicate the category of material required and if intended for use as boiler tubes, superheater tubes, or pressure pipes. For Categories I and III the reference test temperature is also to be given (see Q 101(c)).

(c) At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of material. In such cases short lengths may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

(d) Alternatively, steel tubes or pipes which comply with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section

Manufacture

702 (a) For Category I the steel is to be either silicon or aluminium killed. (See Table Q 7.1).

For Category II any method of deoxidation may be used except that rimming steel may only be used for design temperatures not exceeding 400°C (750°F).

For Category III the method of deoxidation is to be in accordance with the approved specification.

(b) Tubes and pipes may be manufactured by any of the following methods unless one of these methods is particularly specified on the order:—

Hot Finished Seamless,
Cold Finished Seamless,
Electric Resistance Welded,
Cold Finished Electric Resistance Welded,
Electric Fusion Welded (austenitic stainless
steel only).

If rimming steel strip is used for the manufacture of electrical resistance welded tubes or pipes, the strips are to be rolled in single widths and not slit longitudinally.

For Category III the method of manufacture is to be included in the specification submitted for approval.

(c) Care is to be taken that any non-ferrous metals or their compounds coming into contact with the tubes or pipes during manufacture are not deposited so as to be harmful during subsequent fabrication and operation.

Chemical Composition

703 For Categories I and II the chemical composition is to comply with the requirements given in Table Q 7.1.

The chemical composition of steel for Category III is to comply with the approved specification.

Heat Treatment

704 For Categories I and II tubes and pipes are to be supplied in the condition detailed in Table Q 7.2.

For Category III the heat treatment is to comply with the approved specification.

Test Material

705 (a) Tests are to be made on straight tubes and pipes after completion of all drawing and heat treatment operations.

(b) Category I. Tubes and pipes are to be presented for test in batches. Each batch is to contain not more than 400 lengths when the outside diameter is not more than $114,3 \text{ mm } (4\cdot5 \text{ in})$, or not more than 200 lengths when the outside diameter is more than $114,3 \text{ mm } (4\cdot5 \text{ in})$.

Where heat treatment has been carried out, a batch is to consist of tubes or pipes of the same size, manufactured from the same cast of steel and subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch type furnace.

Where no heat treatment has been carried out, a batch is to consist of tubes or pipes of the same size manufactured from the same cast of steel and by the same process of manufacture.

At least 2 per cent of the number of lengths in each batch are to be selected at random for the preparation of tests at ambient temperature. Each boiler tube selected for test is to be subjected to tensile, flattening and expanding tests. The expanding test is to be made at each end of each sample length.

Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

(c) Tensile tests at elevated temperature are to be taken from each cast unless the weight of finished material is greater than 30 000 kg (30 tons) in which case one extra test is to be taken from each 30 000 kg (30 tons) or fraction thereof.

These tensile tests at elevated temperature are not required when:—

- (i) the reference test temperature is 100°C or less,
- (ii) the minimum specified value of the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value,
- (iii) the actual tensile strength at ambient temperature exceeds by at least 5 kg/mm² (3·2 ton/in²) the minimum specified tensile strength. This applies only to carbon and carbon-manganese steels,
- (iv) the manufacturer has obtained certification of elevated temperature proof stress values as detailed in 706(d).
- (d) Category II. Tubes and pipes are to be presented for test in batches. Each batch is to contain not more than the number of lengths permitted in Category I but may consist of tubes or pipes of the same size, manufactured by the same method from material of the same specification.

Tests at ambient temperature are to be taken as for Category I. Tensile tests at elevated temperature are not required.

(e) Category III. Tubes and pipes are to be presented for test in batches and tests taken in accordance with the

requirements for Category I except that tests at elevated temperatures are not required. In addition for Category III(a) material a set of three Charpy V-notch test pieces is to be taken from each batch. When the wall thickness is insufficient to permit the preparation of standard Charpy test pieces then the largest possible subsidiary test piece is to be prepared, see Q 208.

(f) All test pieces are to be prepared in accordance with the requirements of Q 2.

Mechanical Properties

706 (a) Category I. The results of all tensile tests are to comply with the values given in Table Q 7.3. The lower yield or 0,2 per cent proof stress values at elevated temperature are to be determined in accordance with Q 205 at the reference test temperature given in the order.

The flattening test for boiler and superheater tubes and for pressure pipes is to be carried out in accordance with Q 209. The test is to be continued until the distance between the platens, measured under load is not greater than the value given by the formula:—

$$H = \frac{t(1+c)}{c + \frac{t}{D}}$$

where H = distance between platens, in mm (in),

t = specified thickness of the tube, in mm (in),

D = specified outside diameter of the tube, in mm (in),

C = a constant depending on the steel.

Steel	Values for C
Carbon 33/45	0,09
35/47	0,09
42/54	0,07
1Cr 1Mo	0,08
2½Cr 1Mo	0,08
½Cr ½Mo ½V	0,08
17, 13 Mo	0,09
18, 12 Nb	0,09
18, 10 Ti	0,09

For pressure pipes, bend tests may be taken as an alternative for flattening tests and are to be carried out in accordance with Q 207. The test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 7.3.

The drift expanding test specified for boiler and superheater tubes is to be carried out in accordance with Q 210. The test is to be continued until the increase in outside diameter is not less than the following values.

Outside diameter	Minimum increase per cent
Up to and including	
63,5 mm (2·5 in)	17
Over 63,5 mm (2.5 in)	11

Stress rupture values for design purposes are given in Table Q 7.5.

(b) Category II. The results of tensile rests at ambient temperature are to comply with the values given in Table Q 7.4. For design purposes, nominal values of the yield or 0,2 per cent proof stress at elevated temperatures are given in Table Q 7.4. Stress rupture values are given in Table Q 7.5.

Expanding and flattening or bend tests are to be carried out as specified for Category I, the maximum diameter of the former for the bend test is given in Table Q 7.4.

(c) Category III. The Charpy V-notch tests are to be made at or below the reference test temperature given in the order. The results of the tensile, Charpy V-notch and flattening or bend tests are to comply with the approved specification.

Certification of Lower Yield or 0,2 per cent Proof Stress Values at Elevated Temperatures

(d) For Category I material or other approved grades, as an alternative to taking tensile tests at elevated temperature in accordance with 705(c), individual manufacturers may submit for analysis and approval comprehensive test data for a specific grade of steel to demonstrate the lower yield or 0,2 per cent proof stress values at elevated temperatures which can be consistently obtained. This data will be assessed on a statistical basis to determine the 95 per cent lower confidence limit. When a manufacturer is approved on this basis routine tensile tests at elevated temperature will not be required except for periodic check tests at the discretion of the Surveyors.

Manufacturers requiring this form of certification are to submit the following information and test data from at least 45 batches taken from not less than 10 different casts for each grade of steel:—

- (1) Ladle analysis including residual elements.
- (2) Method of deoxidation.
- (3) Method of manufacture.
- (4) Details of heat treatment.
- (5) Results of tensile tests at ambient temperature:— Yield stress, tensile strength and percentage elongation.
- (6) Results of tensile tests at elevated temperatures:— Lower yield or 0,2 per cent proof stress values at 100, 150, 200, 250, 300, 350, 400, 450°C or higher if appropriate for the grade of steel being tested.
- (7) Thickness of tubes or pipes.

The test data are to be representative of the tensile range specified for the grade and also the range of thickness which will be manufactured. For carbon and carbon-manganese steels where there is an overlap in the specified tensile strength range, data submitted for one grade may also be considered for adjacent grades provided the properties at ambient temperature comply with the appropriate tensile strength range.

Inspection

707 (a) The tubes and pipes are to be straight, smooth and cylindrical within practical limits. The ends are to be cut square with the axis and are to be ground where necessary to facilitate examination.

They are to be presented for examination under adequate conditions of lighting and are to be examined internally and externally.

(b) In the case of welded tube or pipe the manufacturer is to employ suitable non-destructive methods for the quality control of the weld. It is preferred that this examination is carried out on a continuous basis.

Dimensional Tolerances of Pressure Pipes

(c) The thickness and diameter of each pressure pipe is to be within the following tolerances:—

(i) Hot Finished Seamless

	RATIO O	TOLERANCE		
		up to and including 3%		±15%
THICKNESS		over 3% and up to 10%	N.	±12,5%
	over 10%	up to and including 168,3 m $(6\frac{5}{8} \text{ in}) \text{ o.d.}$ over 168,3 mm $(6\frac{5}{8} \text{ in}) \text{ o.d.}$		±12,5% ±10%
OUTSIDE DIAMETER	Toleran	ace ±1% with a minimum of	±0,5 m	m (0·02 in)

(ii) Cold Finished Seamless

SIZE	Up to and including 219.1 mm $(8\frac{5}{8} \text{ in}) \text{ o.d.}$	over 204 mm (8 in) i.d.
TOLERANCE ON	±10%	up to and including $+15\%$ 6,3 mm ($\frac{1}{4}$ in) thick -0%
THICKNESS		over 6,3 mm (\frac{1}{4} in) +10% thick -0%
TOLERANCE ON INSIDE DIAMETER	-	$+0.8 \text{ mm } (\frac{1}{3 \cdot 2} \text{ in}) \\ -1.6 \text{ mm } (\frac{1}{1 \cdot 3} \text{ in})$
TOLERANCE ON OUTSIDE DIAMETER	±1%	3 × 10 × 10 × 10 × 10 × 10 × 10 × 10 × 1

(iii) Electric Resistance Welded

THICKNESS (except at weld)	TOLERANCE
Up to and including 139,7 mm ($5\frac{1}{2}$ in) o.d.	±7,5%
Over 139,7 mm $(5\frac{1}{2} \text{ in})$ o.d.	±10%
OUTSIDE DIAMETER	$\pm 1\%$ with a minimum of ± 0.5 mm (0.02 in)

Note:—At the weld the external fin is to be removed completely, i.e., flush with the outside surface of the pipe. Where practicable, the internal fin is to be removed throughout the length of the pipe so that its maximum height shall not exceed 8% of the specified thickness or 0,25 mm (0.01 in) whichever is the greater.

Dimensional Tolerances of Boiler and Superheater Tubes

(d) The thickness and diameter of each tube is to be within the following tolerances which apply only to plain tubes:—

(i) Hot Finished Seamless

THICKNESS	Tolerance $\pm 12.5\%$
OUTSIDE DIAMETER	$\pm 1\%$ with a minimum of ± 0.5 mm (0.02 in)

(ii) Cold Finished Seamless: Carbon and Low Alloy Steel: Cold Finished Electric Resistance Welded: Carbon and Low Alloy Steel

THICKNESS	Tolerance $\pm 7.5\%$
OUTSIDE DIAMETER	$\pm 0.5\%$ with a minimum of ± 0.1 mm (0.004 in)

(iii) Cold Finished Seamless: Austenitic Steel

THICKNESS	TOLERANCE
up to and including 3,2 mm (0·128 in)	±10%
over 3,2 mm (0·128 in)	±7,5%
OUTSIDE DIAMETER	±0,5% with a minimum of 0,15 mm± (0.006 in)

(iv) Electric Resistance Welded

THICKNESS (except at weld)	TOLERANCE
up to and including 3,2 mm (0·128 in)	±10%
over 3,2 mm (0·128 in)	±7,5%
OUTSIDE DIAMETER	$\pm 0.75\%$ with a minimum of ± 0.3 mm (0.012 in)

Note:—At the weld the external fin is to be removed completely, i.e., flush with the outside surface of the tube. The internal fin is also to be removed throughout the length of the tube so that the maximum height of fin is not greater than 0,25 mm (0.010 in).

Hydraulic Tests

(e) Each boiler or superheater tube and each pressure pipe is to be subjected to a hydraulic test at the manufacturer's works. The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test may be accepted.

The test pressure is to be 1,5 times the design pressure or 70 kg/cm² (1000 lb/in²) whichever is the greater. The test pressure is not, however, to exceed that calculated from the formula

$$P = \frac{200 \text{ s t}}{D} \qquad \left(P = \frac{4480 \text{ s t}}{D}\right)$$

where P = test pressure, in kg/cm^2 (lb/in^2),

D = nominal outside diameter, in mm (in),

t = nominal wall thickness, in mm (in),

 $s = 0.40 \times \text{minimum specified tensile strength, in } \text{kg/mm}^2 (\text{ton/in}^2).$

Repair of Defects

708 The repair of minor defects by welding can be accepted subject to compliance with the requirements of Q 108.

Identification

709 Tubes and pipes are to be identified in accordance with Q 109. It is recommended that hard stamping be restricted to the end face but may be accepted in other positions in accordance with national standards and practice.

Documentation

710 The manufacturer is to supply the information detailed in Q 110.

Extract from Chapter E for reference

Steel Pipes

E 508 Steel pipes for a design pressure exceeding 17,5 kg/cm² (250 lb/in²) or a temperature exceeding 220°C (428°F), and all feed pipes and pressure pipes conveying heated oil are to be manufactured and tested in accordance with the requirements of Q 7. Where it is proposed to use materials for pipes other than shown in Q 7, the information called for in E 511 (a) is to be submitted for consideration.

TABLE Q 7.1

Chemical Composition of Tubes and Pipes

Grade of Steel	Tens	ile Stress	Method of Deoxidation				Chem	nical Compositio	on of Ladle Sa	mples—Percer	ntage			
Steel	kg/mm ²	ton/in ²	Deoxidation	С	Si	Mn	s	P			Residua	l Elements		
Carbon	35-47	22 · 2-29 · 8	Silicon or aluminium	0,20 max.	0,10-0,35	0,40-0,90	0,050 max.	0,050 max.						
Category I	42-54	$26 \cdot 7 - 34 \cdot 3$	killed	0,25 max.	0,10-0,35	0,40-1,00	0,050 max.	0,050 max.				00 max. 25 max.		
Carbon	33-45 35-47	21·0-28·6 22·2-29·8	Any method but see	0,18 max.	- 0,35 max.		0,050 max.	0,050 max.			Mo 0,1	0 max. 0 max.		
Category II	42-54	26 · 7 – 34 · 3	Note 1 for rimmed steel					0,050 max.			Total 0,7	0 max.		
						13.5	1 5		Ni	Cr	Мо	Cu	v	Sn
Low Alloy 1Cr-1Mo	42-63	26 · 7 – 40 · 0	1	0,10-0,15	0,10-0,35	0,40-0,70	0,040 max.	0,040 max.	0,30 max.	0,70-1,10	0,45-0,65	0,25 max.		0,03 max
2½Cr-1Mo	42–57 50–70	26·7-36·2 31·7-44·4		0,08-0,15	0,10-0,50	0,40-0,70	0,040 max.	0,040 max.	0,30 max.	2,00-2,50	0,90-1,20	0,25 max.	-	0,03 max
$\frac{1}{2}$ Cr $-\frac{1}{2}$ Mo $-\frac{1}{4}$ V		29 · 8 – 39 · 4	Silicon	0,15 max.	0,10-0,35	0,40-0,70	0,040 max.	0,040 max.	0,30 max.	0,25-0,50	0,50-0,70	0,25 max.	0,22-0,30	0,03 max
High Alloy 17-13-Mo	52-67	33 • 0-42 • 5	killed	0,04-0,09	0,75 max.	1,00-2,00	0,030 max.	0,040 max.	12,0-14,0	16,0-17,5	2,00-2,75	-	-	_
18-12-Nb (Note 2)	52-67	33 · 0 – 42 · 5	1	0,04-0,09	0,20-0,80	0,50-2,00	0,030 max.	0,040 max.	11,0-13,0	17,0-19,0		_	V_1X	-
18-10-Ti (Note 3)	52-67	33.0-42.5	J	0,04-0,09	0,20-0,80	0,50-2,00	0,030 max.	0,040 max.	9,0-13,0	17,0-20,0		-	-	

Notes: 1. Rimmed steel is only to be used for applications where the design temperature does not exceed 400°C (750°F).

^{2.} Niobium+Tantalum. Minimum 10×% Carbon. Maximum 1,10%.

^{3.} Titanium. Minimum 4×% Carbon. Maximum 0,60%.

TABLE Q 7.2

Heat Treatment of Tubes and Pipes

GRADE OF	STE	EL		COL	IDITIO:	N OF S	UPPL	X.			CATEGORY
Carbon Hot Finished Sea	mles	s		As rolled or Normalized 880/920°C				***	***	(Note 1) (Note 2)	I & II I & II
Cold Finished Sea	amles	18	*** 1	37 11 1 000 100000		***	***	***	***	(Note 3) (Note 2)	II & II
Electric Resistan	ce W	elded		Normalized 880/920°C		***		100	***	(Note 2)	I & II
Cold Finished E.	R.W.			Normalized 880/920°C	***	***			244	(Note 2)	I & II
ALLOY STEEL 1Cr-½Mo .				Normalized 900/960°C	Ten	npered	640/6	90°C	(6.6.6)		I & II
2½Cr-1Mo .				Annealed 920/960°C or Normalized 920/960°C	Ten	 apered	650/7	50°C	***	(Note 4) (Note 5)	I & II I & II
$\frac{1}{2}$ Cr $-\frac{1}{2}$ Mo $-\frac{1}{4}$ V .				Normalized 950/980°C	Ten	apered	660/7	10°C	225	(Note 6)	I & II
17-13-Мо .				Solution treated 1 050/1	100°C	1			***		I & II
18-12-Nb .		***		Solution treated 1 070/1	120°C)					I & II
18-10-Ti .				Solution treated 1 090/1	140°C	1	***				I & II

Notes.

- 1. Provided the hot finishing temperature is sufficiently high to soften the material.
- 2. At the option of the manufacturer tubes and pipes may also be tempered after normalizing.
- 3. Annealed tubes and pipes are only to be used for applications where the design temperature does not exceed 400°C (750°F).
- 4. Where the cooling rate from annealing temperature exceeds 100degC per hour, the material is to be tempered at 650/700°C.
- 5. For tempering temperatures of 720°C or higher, the time above this temperature is not to exceed 30 minutes.
- 6. Time at tempering temperature is to be not less than 3 hours.

TABLE Q 7.3

Mechanical Properties of Tubes and Pipes Category I

Grade of Steel	Yield Stress Minimum kg/mm ²	Tensile Strength kg/mm ²	Elongation on 5,65 V So				Minin	ium Lowe	r Yield St	ress or 0,2	% Proof	Stress, kg/	mm ²		
	rg/mm-		% Mini- mum	of former	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon	21,3	35-47	27	3t	18,6	18,4	18,0	17,0	14,8	13,2	12,0	11,7			
Carbon	25,2	42-54	23	4t	20,5	20,2	19,4	18,3	16,1	14,6	14,0	13,4			
1C r−1 Mo	23,6	42-63	17	4t	22,9	22,0	21,3	19,1	16,7	15,1	14,8	14,5	14,2		
2½Cr-1Mo	23,6	42-57	20	4t	20,0	18,1	15,6	15,1	14,6	14,0	13,5	13,2	12,8	12,3	
(Note 1) 2½Cr-1Mo (Note 2)	26,8	50–70	16	4t	25,8	25,5	25,0	24,0	23,0	22,0	21,0	20,0	19,0		
½Cr−½Mo−½V	30,0	47-62	20	4t	25,8	25,5	25,0	24,0	23,0	22,0	21,0	20,0	19,0		
17-13-Mo	19,0	52-71	30	3t	110				1117		4				
18-12-Nb	21,0	52-71	30	3t											
18–12–Ti	17,0	52-71	30	3t											

t = thickness of bend test piece.

NOTES. 1. Annealed condition.

2. Normalized and tempered condition.

LLOYD'S REGISTER OF SHIPPING

TABLE Q 7.3

Mechanical Properties of Tubes and Pipes Category I

Grade of Steel	Yield Stress Minimum	Tensile Strength ton/in ²	Elonga- tion on 5.65 V So	Bend Test Maximum diameter			Minim	nm Lower	Yield Stre	ess or J-2	% Proof S	tress, ton/i	n ² n ²		
	ton/in ²		% Mini- mum	of former	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon	13.5	22 • 2-29 • 8	27	3t	11·8 26 500	11·7 26 200	11·4 25 600	10·8 24 200	9·4 21 100	8·4 18 800	7·6 17 100	7·4 16 600			
					9			16							
Carbon	16.0	26 · 7 – 34 · 3	23	4t	13·0 29 200	12·8 28 700	12·3 27 600	11·6 26 000	10·2 22 900	9·3 20 800	8·9 19 900	8·5 19 100			
1C r−½ Mo	15.0	26 · 7 – 40 · 0	17	4t	14·5 32 400	14·0 31 300	13·5 30 200	12·1 27 100	10.6 23 800	9·6 21 500	9·4 21 100	9·2 20 600	9·0 20 200		
2½Cr-1Mo (Note 1)	15.0	26 · 7 – 36 · 2	20	4t	12·7 28 400	11-5 25 800	9·9 22 200	9·6 21 500	9·3 20 800	8·9 19 900	8·6 19 200	8·4 18 800	8·1 18 200	7·8 17 500	
2½Cr-1Mo	17.0	31 - 7 - 44 - 4	16	4t	16.4	16-2	15.9	15.2	14.6	14.0	13.3	12.7	12-1		
(Note 2)	2,0				36 700	36 300	35 600	34 000	32 700	31 300	29 700	28 400	27 000		
½Cr−½Mo−½V	19-0	29 · 8 – 39 · 4	20	4t	16·4 36 700	16·2 36 300	15·9 35 600	15·2 34 000	14·6 32 700	14·0 31 300	13·2 29 700	12·7 28 400	12·1 27 000		
17-13-Mo	12.0	33 · 0-45 · 1	30	3t	THE REAL PROPERTY.	7446,2								14.5	
18-12-Nb	13.5	33 · 0-45 · 1	30	3t											
18-10-Ti	11.0	33 · 0-45 · 1	30	3t											

t = thickness of bend test piece.

Notes. 1. Annealed condition.

2. Normalized and tempered condition.

Table Q 7.4

TABLE Q 7.4

Mechanical Properties of Tubes and Pipes Category II

Grade of Steel	Yield Stress	Tensile	Elonga- tion on	Bend Test Maximum			Low	er Yield S	tress or 0,	2 % Proof	Stress, kg	/mm ² (No	te 1)		
Grade of Steel	Minimum kg/mm ²	Strength kg/mm ²	5,65 V So % Mini- mum	Maximum diameter of former	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon	16,5	33-45	27	3t	12,6	12,1	11,7	10,7	9,2	7,3	7,2	7,1			
	17,8	35-47	27	3t	13,6	13,3	13,0	11,7	10,2	8,4	8,2	8,2			
	21,5	42–54	23	4t	18,0	17,6	17,3	15,8	14,2	12,6	12,3	12,0			
1Cr−½Mo	22,5	42-63	17	4t	19,5	18,7	18,1	16,2	14,2	12,8	12,6	12,3	12,1		
2½Cr-1Mo (Note 2)	21,5	42–57	20	4t	17,0	15,4	13,3	12,8	12,4	11,9	11,5	11,2	10,9	10,4	
2½Cr-1Mo (Note 3)	25,0	50–70	16	4t	21,9	21,7	21,3	20,4	19,5	18,7	17,7	17,0	16,1		
½Cr-½Mo- <u>↓</u> V	28,0	47-62	20	4t	21,9	21,7	21,3	20,4	19,5	18,7	17,7	17,0	16,1		
17-13-Mo	19,0	52-71	30	3t	0.000	1/400	1,300	Trest	1920	11 100	11 100	17 100			
18-12-Nb	21,0	52-71	30	3t											
18-10-Ti	17,0	52-71	30	3t											

t = thickness of bend test piece.

Notes. 1. The values for lower yield stress or 0,2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by tests.

- 2. Annealed condition.
- 3. Normalized and tempered condition.

or in British units:-

TABLE Q 7.4

Mechanical Properties of Tubes and Pipes Category II

Grade of Steel	Yield Stress	Tensile Strength	Elonga- tion on	Bend Test Maximum	by byny		Lov	wer Yield	Stress or (1 · 2 % Proc	of Stress, l	b/in ² (Not	e 1)		
I = II - II	Minimum ton/in ²	Strength ton/in ²	% Mini- mum	diameter of former	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon	10-5	21 · 0 – 28 · 6	27	3t	17 900	17 200	16 600	15 200	13 100	10 400	10 200	10 100			
	11.3	22 · 2-29 · 8	27	3t	19 300	18 900	18 500	16 600	14 500	11 900	11 700	11 700			
CI-TAO YA	13.7	26 · 7 – 34 · 3	23	4t	25 600	25 000	24 600	22 500	20 200	17 900	17 500	17 100	101		
1Cr−½Mo	14.3	26 · 7 – 40 · 0	17	4t	27 700	26 600	25 700	23 000	20 200	18 200	17 900	17 500	17 200		
2½Cr-1Mo	13.7	26 · 7 – 36 · 2	20	4t	24 200	21 900	18 900	18 200	17 600	16 900	16 400	15 900	15 500	14 800	
(Note 2) 2½Cr-1Mo	15.9	31 - 7-44 - 4	16	4t	31 100	30 900	30 300	29 000	27 700	26 600	25 200	24 200	22 900	TOPY	
(Note 3)	100			1	100	1841	101			11.1	ma			*	
<u>1</u> Cr−1/2 Mo−1/2 V	17.8	29 · 8 – 39 · 4	20	4t	31 100	30 900	30 300	29 000	27 700	26 600	25 200	24 200	22 900		
17-13-Mo	12.0	33 · 0 - 45 · 1	30	3t	19/9	171	7-81		103	-			Tom		
18-12-Nb	13.5	33 · 0 - 45 · 1	30	3t											
18-10-Ti	11.0	33 · 0 – 45 · 1	30	3t											

t=thickness of bend test piece.

Notes. 1. The values for lower yield stress or 0.2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by tests.

- 2. Annealed condition.
- 3. Normalized and tempered condition.

TABLE Q 7.5

Average Values for Stress to Rupture in 100 000 hrs. Units kg/mm²

Temp. °C	Carbon Steel	Alloy Steels						
		1Cr-1Mo	2‡Cr-1Mo	‡Cr-1Mo-1V	17-13-Mo	18-12-Nb	18-10-T	
350	21,5				The second	000.001	1001	
360	19,7					CD0 BD		
370	17,9					100 E		
380	16,0					CUST III		
390	14,3					ON UP		
400	12,5					UD- VI		
410	10,8					and a second	0.03	
420	9,4					OME:	183	
430	8,3					808-11		
440	7,3							
450	6,5	32,0	00.01	33,1	(LDA XI)			
460	5,7	28,4	udg to	29,9	100 00		(1)	
470	5,0	25,0	0005.95	26,9	E00 85	COLL		
480	4,4	21,6	21,4	24,1	00700	0000		
490	3,8	18,3	19,2	21,4	000 /2			
500	3,3	15,1	17,2	18,9	LUM III	CONTRACT OF		
510		12,4	15,1	16,5	(00.71			
520		10,1	13,2	14,2	1.009-33			
530		8,0	11,5	12,1	003/TE			
540		6,3	9,9	10,2				
550		5,0	8,5	8,8	20,8	16,1	19,5	
560	TANK UP	4,1	7,2	7,4	19,2	14,6	18,1	
570	- BOSE-101 1	3,2	6,1	6,5	17,6	13,2	16,8	
580	008.81	2,4	5,2	5,5	16,1	11,8	15,6	
590	16/67		4,4	William I	14,5	10,5	14,3	
600	Ture	BOIL T	3,8	AUG TO THE REAL PROPERTY.	13,1	9,3	13,1	
610	000.11	000.00			11,5	8,2	11,8	
620	1000.01				10,4	7,2	10,5	
630	1000				9,1	6,3	9,3	
640	- CERT				8,0	5,5	8,2	
650	The same of the sa	100101			7,1	4,7	7,2	
660	V-1				6,0	4,1	6,1	
670	0091				5,3	3,5	5,2	
680	100				4,6	3,0		
690	1000					2,5		
700						2,0	001	
710	000-10-		7.1			1,7		
720								

or in British units:-

Temp. °C	Carbon Steel	Alloy Steels						
		1Cr-iMo	2‡Cr-1Mo	<u></u> 2Cr−2Mo−2∇	17-13-Mo	18-12-Nb	18-10-T	
350	30 600					E.12 1	010	
360	28 000	2						
370	25 400							
380	22 800							
390	20 300							
400	17 800					TO STATE OF THE ST	010	
410	15 300							
420	13 400		1 2 1 2	5 . 54				
430	11 800							
440	10 400		100					
450	9200	45 500	THE R	47 000	THE RESERVE		100	
460	8000	40 400		42 500				
470	7100	35 600		38 300				
480	6200	30 700	30 500	34 300				
490	5400	26 000	27 300	30 400				
500	4700	21 500	24 400	26 900				
510		17 600	21 500	23 500				
520		14 400	18 800	20 200				
530		11 400	16 400	17 200				
540		9000	14 100	14 500			194	
550		7100	12 100	12 500	29 600	22 800	27 800	
560		5800	10 300	10 500	27 300	20 800	25 800	
570		4600	8700	9200	25 100	18 800	24 000	
580		3400	7400	7800	22 800	16 800	22 200	
590			6300		20 600	15 000	20 400	
600			5400		18 600	13 200	18 600	
610		- 64			16 600	11 600	16 800	
620	84	1.4.1.4			14 800	10 300	15 000	
630		. 67			13 000	9000	13 200	
640					11 400	7800	11 600	
650		a a			10 100	6700	10 300	
660					8700	5800	8700	
670				E 11 625	7600	4900	7400	
680 690		10,8			6500	4300 3600		
700					,			
710						2900 2500		
720						2000		

Section 8

CAST IRON CRANK SHAFTS

General

801 Cast iron crank shafts are to be cast at an approved foundry to an approved material specification, and to approved manufacturing and inspection procedures. The inspection procedure will include the approved size, form and location of the test blocks on the crank shaft castings.

Grades of Cast Iron

802 Any suitable grade of flake graphite, low alloy, acicular or spheroidal or nodular graphite cast iron may be used for crank shafts. The minimum tensile strength of the particular grade of cast iron, corresponding to the section of the crank shaft, is not to be less than that detailed in the approved Specification. (See H 202, also N 330 and N 331).

Process of Manufacture

803 The raw materials of a charge such as pig iron, return scrap and scrap steel, are to be specially selected. The melt is to be closely controlled particularly with regard to temperature, time and composition when inoculated irons are being produced. Where such irons are made, the casting temperature and the time between completion of the inoculation and finished pouring of the castings are to be recorded. The records are to be available to the Surveyor at any time.

The Surveyor is to be provided with a statement giving the chemical composition of the material used for each crank shaft or batch of crank shafts.

Heat Treatment

804 In general, crank shaft castings other than those which are fully annealed, normalized or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.

805 All heat treatments of castings are to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means of temperature control of the furnace charge. Each casting is to be slowly and uniformly heated to the necessary temperature.

806 Unless otherwise agreed, test blocks are not to be removed from castings until all heat treatments have been completed. Test blocks are to receive the same heat treatment as the castings and are to be removed from castings and cut to provide test pieces by methods which do not impair or modify the characteristics of the materials. Flame cutting is not permitted for the removal of test blocks from a casting or for cutting up test blocks to provide test pieces.

Provision of Test Material

807 Unless otherwise approved, test material is to be provided by test blocks cast integral with or gated from each crank shaft. The test blocks are to be sufficient in number to allow of re-tests, if required. The dimensions of test blocks are to be such as to ensure that the material properties are similar to those of the average section of the crank shaft casting.

Dimensions of Test Pieces

808 The diameter of a tensile test piece is to be as large as practicable. In general, it should not be less than 14 mm (0.564 in) diameter.

A small flat is to be ground on each crank shaft casting and the Brinell hardness determined.

Number of Tests

809 At least one tensile test piece is to be taken for each crank shaft.

Testing Machines

810 Tensile tests are to be carried out by competent personnel in an approved machine of adequate capacity. The machine is to be maintained in an efficient and accurate condition and is to be checked and calibrated at suitable intervals agreed by the Society.

Mechanical Properties

811 The results of the tensile and hardness tests are to comply with the approved specification for the material.

Additional Tests Before Rejection

812 Where the results of a tensile test do not comply with the specification, two re-tests are permitted. If the

results of both re-tests are satisfactory the casting is acceptable as regards the tensile test. If either of the re-tests fails the casting is unacceptable. For castings which were fully heat treated, re-heat treatment followed by re-testing may be permitted provided the size of the residue of the test block(s) is suitable, and the agreement of the Surveyor is obtained.

Batch Testing

813 In the case of small shafts which are produced in quantity and are heat treated together, a system of batch testing may be adopted with the agreement of the Surveyor. In these cases, however, not less than two test pieces are required per melt of which one is to represent the first shaft to be cast and the other the last shaft to be cast.

Inspection of Castings

814 Where surplus material is to be removed from crank shaft castings before despatch, a machining method is to be employed. Flame cutting is not permissible.

Finished castings which have passed test are to be examined by the Surveyor before despatch. The castings are to be in a clean condition so that all surfaces may be examined including those of bores. Castings are to be free from cracks and other detrimental defects. Cast iron crank shafts are not to be repaired by welding and blemishes are not to be plugged with a filler.

Branding

815 Every casting, after it has withstood satisfactorily the prescribed tests and inspection, is to be clearly marked by the Surveyor indicating that the casting has complied with the requirements of the Society.

In the event of any casting proving unsound during machining or at any subsequent stage of survey, it is to be rejected notwithstanding any previous certificate of satisfactory test and inspection.

Surface Treatment

816 Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crank shafts, details of the process are to be submitted for approval. Before such a process is applied to a crank shaft it is to be demonstrated by procedure tests and to the satisfaction of the Surveyor, that the process is suitably controlled and does not impair the strength or soundness of the material.

Section 9

COPPER ALLOY PROPELLERS AND PROPELLER BLADES

General

901 The requirements of this Section are applicable to propeller castings of the following non-ferrous materials:—

- (a) Manganese bronze or high tensile brass with a minimum tensile strength of 44 kg/mm² (28 ton/ in²).
- (b) High tensile aluminium bronzes with a minimum tensile strength of 63 kg/mm² (40 ton/in²).

Particulars of chemical composition and mechanical properties of proprietary alloys are to be submitted for information.

- 902 Where it is proposed to use other non-ferrous materials or different grades of type (a) and (b) alloys, full particulars are to be submitted for consideration.
- 903 Castings are to be clean and free from harmful defects and are to be tested and inspected at the makers' works. In the event of any casting proving defective in the course of subsequent machining such casting may be rejected notwithstanding any previous certification of satisfactory test.

Provision of Test Samples

904 Test samples, sufficient for the preparation of at least three test pieces, are to be provided for each casting. The test samples are to be of approved form and may be separately cast or integral with the casting.

905 Separately cast test samples:— These may be adopted at works where Surveyors are in frequent attendance. The procedure for identifying the test samples and the propeller casting is to be approved by the Surveyors who in cases of doubt may require that check analyses of sample and casting be made.

The samples are to be separately cast at the same time and from the same metal as the casting which they represent, and are to be poured into moulds of the same material as that used for the casting. Where a casting is made from more than one ladle test samples are to be provided for each ladle.

906 Integral test samples:— These are to be provided as blocks on the surfaces of the casting. Samples gated from the casting are not acceptable.

Note.—With the object of obtaining sound test blocks and of permitting free contraction of the propeller casting, it is preferable that the test blocks be arranged axially on the hub instead of on the blades at mid-radii.

Mechanical Properties

907 Test pieces are to be 14 mm (0.564 in) diameter with a gauge length of 50 mm (2 in) or of other similar standard. At least one tensile test is to be made for each casting and for each ladle if 905 is applicable. The test results are to comply with the requirements of Table Q 9.1 or of a specification specially approved.

If the first test piece fails to meet requirements, then the two remaining test pieces are to be broken; if these also fail the casting is to be rejected.

TABLE Q 9.1

Material	Minimum T kg/mm ²	Minimum Elongation per cent on 50 mm (2 in) gauge length	
MARCHAI	Integral test piece Separately cas test piece		
(a) Manganese Bronze	44(28)	47(30)	20
(b) Aluminium Bronze	63(40)	66(42)	15

Note. The values in the table are applicable to test pieces and are not necessarily obtainable from all parts of the castings. In general it can be expected that the mechanical properties of a propeller, especially in the thick root sections of the blades, will be inferior to those of the test piece.

15th July, 1971

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APPENDICES TO CHAPTERS P AND Q

APPENDIX

STEEL MANUFACTURERS

The following establishments have complied with the requirements for quality and testing of steel and have been recognized by the Committee.

FIRMS IN GREAT BRITAIN AND IRELAND

Allied Ironfounders, Ltd., Larkhall Steel Foundry, Larkhall, Lanarkshire. (Castings)
Alston Foundry Co., Ltd., Nent Force Foundry, Alston, Cumberland. (Small castings)
Andrews Toledo, Ltd., Toledo Steel Works, Neepsend, Sheffield. (Ingots and billets)
Baird, Archibald, & Sons, Ltd., Hamilton, Lanarkshire. (Castings)
Baker, W. A., & Co., Ltd., Westgate Works, Newport, Mon. (Castings)
Baker Perkins, Ltd., Peterborough. (Small castings)
Beardmore, William, & Co., Ltd., Parkhead, Glasgow. (Castings, forgings, billets and blooms)
Blackett, Hutton & Co., Ltd., Cleveland Steel Foundry, Guisborough, Yorkshire. (Castings)
Blair, George, & Co., Ltd., Armond Carr Works, Tow Law, Co. Durham. (Castings)
Blair, George & Co., Ltd., Newcastle Alloy Steel Foundry, Newcastle upon Tyne. (Small castings)
Bond's Foundry Co., Ltd., Tow Law, Co. Durham. (Small castings)
British Rail Engineering Ltd., Chester Bridge Works, Crewe. (Castings)
British Rolling Mills, Ltd., Brymill Works, Tipton, Staffs. (Cold drawn bright bars)
British Steel Corporation.

General Steels Division. Divisional Headquarters—Glasgow
Divisional Office (Teesside)—Middlesbrough

Works:-

Appleby-Frodingham, Scunthorpe, Lincs. (Slabs, blooms, billets, plates, sections, bars and rods) Barrow, Barrow-in-Furness, Lancashire. (Billets, bars and sections) Cargo Fleet, Middlesbrough. (Sections and bars) Consett, Consett, Durham. (Plates) Clydebridge, Cambuslang, near Glasgow. (Plates) Dalzell, Motherwell, Lanarkshire. (Plates, sections, bars and blooms) East Moors, Cardiff. (Ingots, blooms, billets, sections and bars) Glengarnock, Glengarnock, Ayrshire. (Sections and bars) Hartlepool, Hartlepool, Co. Durham. (Plates) Irlam, Irlam, Lancashire. (Billets, bars and sections) Lanarkshire, Motherwell, Lanarkshire. (Sections) Monks Hall and Co., Warrington. (Rolling mill for bars) Normanby Park, Scuntherpe, Lines. (Ingots, billets, slabs and bars) Redbourn, Scunthorpe, Lines. (Ingots, billets, bars and slabs) Wm. Robertson, Talbot Stead & Co., Latchford, Warrington. (Cold drawn bright bars) Skelton, Stoke on Trent. (Ingots, billets, bars and sections) Skinningrove, Saltburn-by-the-Sea. (Sections and bars) South Teesside, Middlesbrough. Britannia. (Rolling mills for sections and bars)

Britannia. (Rolling mills for sections and bars)
Cleveland. (Sections and bars)
Lackenby. (Ingots, billets, sections, bars, strips and plates)
Redcar. (Ingots)

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Victoria, Coatbridge, Lanarkshire. (Sections and bars)

Warrington, Warrington, Lancs. (Rolling mills for sections and bars)

Workington, Workington, Cumberland. (Ingots, blooms, billets, slabs and bars for manufacture of small forgings (Acid Bessemer or electric steel), rolled sections (electric steel only))

Strip Mills Division. Divisional Headquarters—Cardiff.

Works:-

Ebbw Vale, Ebbw Vale, Mon. (Ingots)

Jarrow, Jarrow-on-Tyne. (Rolling mills for sections and rounds)

Lancashire and Corby, Corby, Northants. (Ingots, billets, slabs and strips)

Llanwern, Newport, Mon. (Light plates)

Port Talbot, Glam. (Ingots, plates and strips)

Ravenscraig, Ravenscraig, Lanarkshire. (Ingots, rolled slabs and thin plates)

Shotton, Shotton, Flints. (Ingots, slabs and light plates)

Whitehead, Newport, Mon. (Rolling mill for strips, bars and sections)

Special Steels Division. Divisional Headquarters—Sheffield, Works:—

Bilston, Staffordshire. (Tube ingots, billets and bars)

Brymbo, Wrexham, Denbighshire. (Electric steel for forgings and re-rolling)

Craigneuk, Motherwell. (Castings, forgings, billets and bars)

Grimesthorpe, Sheffield. (Ingots and castings)

Hallside, Glasgow. (Castings and billets)

Openshaw, Manchester. (Forgings, bars, plates up to ½ inch in thickness)

Park Gate, Rotherham. (Ingots, billets, bars, sections and strips)

River Don, Sheffield. (Ingots, forgings, plates and billets)

Steel Peech and Tozer, Rotherham. (Ingots, blooms, bars and forgings)

Stocksbridge, Sheffield. (Ingots, blooms, billets, slabs and plates)

Taylor Bros, Manchester. (Ingots)

Tinsley Park, Sheffield. (Ingots, blooms, billets, slabs and bars)

Toll Cross, Glasgow. (Castings)

Tubes Division. Divisional Headquarters—Corby, Northants.

Works:-

Clydesdale, Bellshill, Lanarkshire. (Ingots, billets, slabs and strips for tubes)

Briton Ferry Steel Co., Ltd., Briton Ferry, Neath, Glamorgan. (Ingots)

Broadbent, H., & Son Ltd., Foundry Division of Dewrance Triangle Ltd., Ashton-under-Lyne. (Small castings)

Brockhouse Castings, Ltd., Wednesfield, Wolverhampton. (Small castings)

Brown Bayley Steels, Ltd., Sheffield. (Ingots, forgings and bars)

Brown, The David, Gear Industries, Ltd., (Foundry Division), Penistone, Yorks. (Castings)

Brown, Lenox & Co., Ltd., Pontypridd. (Castings)

Cameron Iron Works, Livingston, West Lothian. (Forgings)

Catton & Co., Ltd.,

Yorkshire Steel Foundry, 29, Chadwick Street, Hunslet, Leeds. (Castings)

Pontefract Lane, Leeds. (Small castings)

Coghlan Forge & Rolling Mills, Ltd., and Coghlan Bright Steel, Ltd., Hunslet Forge, Leeds. (Rolling mills for bars)

Crofts (Engineers), Ltd., Thornbury, Bradford. (Castings)

Cruikshank & Co., Ltd., Denny Iron Works, Denny, Stirlingshire. (Small castings)

Doxford & Sunderland Shipbuilding & Engineering Co., Ltd., Wolsingham Steelworks, Wolsingham, Bishop Auckland, Co. Durham. (Ingots and castings)

Dunford Hadfields, Ltd., East Heela Works, Sheffield. (Ingots, blooms, billets, forgings, bars, special sections and castings)

APPENDICES TO CHAPTERS P AND Q

Edgar Allen Foundry, Ltd., Imperial Steel Works, Tinsley, Sheffield 9. (Castings)

Firth Brown, Ltd.,

Atlas Works, Sheffield. (Ingots, forgings, rolled bars and billets)

Scunthorpe Works, Scunthorpe, Lincs. (Castings)

Firth Vickers Stainless Steels, Ltd.,

Sheffield Works, Sheffield. (Rolling mills for plates, bars and sections; also castings)

Staybrite Works, Halesowen, Worcs. (Castings)

Glanmorfa, Ltd., Llanelly. (Castings and ingots)

Guest, Keen & Nettlefolds (South Wales), Ltd., Cardiff.

Castle Works. (Rolling mills for bars and strips)

Tremorfa Works. (Rolling mills for bars and sections)

Halesowen Steel Co., Ltd., The, Halesowen, near Birmingham. (Cold drawn bright bars)

Hamilton, A., & Sons Ltd., Victoria Foundry, East Moors, Cardiff. (Small castings)

Head, Wrightson Steel Foundries, Ltd.,

Light Pipe Hall Road, Stockton-on-Tees. (Castings)

Teesdale Iron Works, Thornaby-on-Tees. (Castings)

Hopkinsons, Ltd., Britannia Works, Huddersfield, Yorkshire. (Castings)

Hyde, Robert & Son, Ltd.,

Clarendon Works, Chesterfield. (Small castings)

North Stafford Steel Foundry, Stoke-on-Trent. (Small castings)

James Mills (Bredbury), Ltd., Bredbury Steel Works, Bredbury, Nr. Stockport. (Rolling mills for bars)

Jessop-Saville, Ltd., Brightside Works, Sheffield. (Ingots, blooms, bars and forgings)

Jopling, E., & Sons, Ltd., Pallion, Sunderland. (Castings)

K. & L. Steelfounders & Engineers Limited, Letchworth, Hertfordshire. (Castings)

Kirkstall Forge Engineering, Ltd., Leeds. (Forgings)

Lake & Elliot, Ltd., Engineers and Founders, Braintree, Essex. (Small castings)

Lilleshall Co., Ltd., St. George's, near Oakengates, Shropshire. (Rolling mills for sections and bars)

Llanelly Steel Co. Ltd., Llanelly Steel Works, Llanelly. (Billets and bars)

Lloyd, F. H., & Co., Ltd.,

James Bridge, near Wednesbury, Staffordshire. (Ingots and castings)

Cardiff Works, Curran Road, Cardiff. (Ingots and castings)

Lloyds (Burton) Ltd., Wellington Works, Burton upon Trent, Derbyshire. (Ingots and castings)

Lloyds (Darlington) Ltd., Darlington. (Small eastings)

Martins (Dundyvan), Ltd., Coatbridge, Lanarkshire. (Rolling mills for sections)

National Steel Foundry (1914), Ltd., The, Kirkland Works, Leven, Fifeshire. (Castings)

North British Steel Group Ltd., Bathgate Road, West Lothian.

Armadale Works, (Castings)

Bathgate Works, (Castings)

Osborn Hadfield Steel Founders, Ltd., Clyde Steel Works, Sheffield. (Castings)

Parker Foundry Ltd., Mansfield Road, Derby. (Small castings)

Patent Shaft Steel Works, Ltd., Wednesbury, Staffordshire.

Porterfield Foundries Ltd., Renfrew. (Castings)

Raine & Co., Ltd., Delta Iron & Steel Works, Derwenthaugh, Newcastle upon Tyne. (Rolling mills for sections and bars)

Redheugh Iron & Steel Co. (1936), Ltd., Teams, Gateshead-on-Tyne. (Rolling mills)

Renton & Fisher, Ltd., Hopetoun Steel Works, Bathgate. (Castings)

Round Oak Steel Works, Ltd., Brierley Hill, Staffordshire. (Ingots, blooms, billets, bars and sections)

Royal Ordnance Factory, Patricroft, Manchester. (Ingots)

Ryder Brothers, Ltd. (Beehive Steel Foundry), Bolton. (Castings)

Shaw, W., & Co., Ltd., Wellington Cast Steel Foundry, Middlesbrough. (Castings)

LLOYD'S REGISTER OF SHIPPING

Spartan Steel and Alloys Ltd., Spartan Works, Birmingham 6. (Ingots)

Spear & Jackson, Ltd., Sheffield. (Ingots and billets)

Steelcast Ltd., Empire Works, Billingham, Teesside. (Castings)

Tennent, R. B., Ltd., Whifflet Foundry, Coatbridge. (Ingots)

Vickers Ltd., Shipbuilding Group, Barrow Engineering Works, Barrow-in-Furness. (Forgings)

Williams, John, (Wishaw), Ltd., Excelsior Iron & Steel Works, Wishaw, Lanarkshire. (Rolling mills for thin plates)

Wilson's Foundry & Engineering Co., Ltd., Bishop Auckland, Co. Durham. (Castings)

Irish Republic.

Irish Steel Holdings Ltd., Haulbowline, Co. Cork. (Ingots, bars and sections)

APPENDICES TO CHAPTERS P AND Q

FIRMS IN COUNTRIES OTHER THAN GREAT BRITAIN AND IRELAND (ALPHABETICALLY ARRANGED)

Note. The place of residence of the Surveyor giving attendance at each works is shown in parentheses.

A.1. Iron & Steel Foundry, Ltd., Vancouver, B.C. (Small castings) (VANCOUVER)

A.G. Der Dillinger Huttenwerke, Dillingen/Saar, Germany. (Ingots and plates) (SAARBRÜCKEN)

A.S.S.A. Acciaierie di Susa Società Anonima, Turin, Italy. Head Office: Turin. Works: Susa. (Castings) (Genoa)

Aceria Bragado S.A.I.C., Bragado, Argentina. (Castings) (Buenos Aires)

Acerias y Forjas de Azcoitia, Azcoitia Guipuzcoa, Spain. (Ingots and small rolled bars) (Bilbao)

Aceros de Galicia, Vigo Spain. (Castings) (Vigo)

Aceros y Fundiciones del Norte Pedro Orbegozo y Cia., S.A., Hernani, (Guipuzcoa), Spain. (Ingots, forgings and rolled bars) (Bilbao)

Aciéries du Furan, St. Etienne (Loire), France. (Electric steel castings) (PARIS)

Aciéries & Fonderies de l'Est, France.

Usine de Colombier-Fontaine. (Small Castings)
(PARIS)

Usine de Sainte-Suzanne. (Small Electric Castings)
(Paris)

Acos Villares S.A. Sao Caetano do Sul, Sao Paulo, Brazil. (Castings, forgings, billets and bars) (SAO PAULO)

Agrometal S.A., Miranda de Ebro Works, Bilbao, Spain. (Castings) (Bilbao)

Ahlström, A., Oy, Osakeyhtio Karhulan Tehtaat, Karhula Bruk, Karhula, Finland. (Castings) (Hel-Sinki Helsingfors)

Aichi Steel Works, Ltd.

Chita Plant, Aichi Prefecture, Japan. (Ingots and bars) (Kobe)

Kariya Plant, Aichi Prefecture, Japan. (Ingots and bars) (Kobe)

Aktiebolaget Jarnforadling, Halleforsnas, Sweden. (Small castings) (STOCKHOLM)

Algoma Steel Corporation, Ltd., Sault St. Marie, Ontario, Canada. (Plates, sections and bars) (TORONTO)

Allard, Usines & Aciéries, Société Anonyme, Mont-sur-Marchienne, near Charleroi, Belgium. (Castings) (Antwerp)

Allard, Usines & Aciéries, Société Anonyme, Turnhout, Belgium. (Small castings) (Antwerp)

Altos Hornos de Mexico, S.A., (A.H.M.S.A.), Monclova, Coah., Mexico. (Plates) (MEXICO CITY)

American Rolling Mill Co., Middletown, O., U.S.A. (Castings and forgings) (CLEVELAND, O.)

Åminnefors Kb, Ky, Åminnefors Stalverk, Åminnefors, Finland. (Ingots, billets, bars and sections) (Åbo)

Amsco Italiana S.p.A., Milan, Italy. (Small castings) (MILAN)

Amurrio, S.A., Talleres de., Amurrio, Alava, Spain. (Steel castings) (BILBAO)

Ando Iron Works Co., Ltd., Tokyo, Japan. (Small forgings) (YOKOHAMA)

ARANZABAL S.A., Vitoria, Alava, Spain. (Small castings) (Bilbao)

"ARBED", Aciéries Réunies de Burbach-Eich-Dudelange,

Division de Belval, Esch-sur-Allzette, Luxembourg. (Ingots, blooms, billets, bars, angle bars, and sections) (Saarbrücken)

Division de Differdange, Differdange, Luxembourg. (Sections and bars) (Saarbrücken)

Division de Dommeldange, Dommeldange, Luxembourg. (Ingots, forgings and castings) (SAAR-BRÜCKEN)

Division d'Esch, Esch-sur-Allzette, Luxembourg. (Ingots, bars and sections) (Saarbrücken)

Division de Burbach, Sarrebruck, Hostenbach Works. (Plates) (Saarbr

Hostenbach Works. (Plates) (Saarbrücken-Saar)

Asano Tekkosho Co., Ltd., Saijo-Shi, Shikoku, Japan. (Small forgings) (Kobe)

Astilleros Espanoles S.A., Factoria de Manises, Valencia, Spain. (Castings and forgings) (VALENCIA)

Astilleros Rio Santiago Ensenada, Buenos Aires, Argentina. (Steel castings) (BUENOS AIRES)

Astilleros y Talleres del Noroeste S.A., El Ferrol del Caudillo, Spain. (Small forgings and small castings) (El Ferrol)

Atlantic Steel Castings Co., The, Chester, Pa., U.S.A. (Castings) (PHILADELPHIA)

Atlas Steels Company, Welland, Ontario, Canada. (Ingots and bars) (TORONTO)

Aubert et Duval, Anciens Ets., Aciéries des Ancizes, Puy de Dome, France. (Ingots, rolled bars and forgings) (PARIS)

August Thyssen - Hutte A.G., Duisburg - Hamborn, Germany.

Area Hamborn. Steelworks Beeckerwerth, Bruckhausen and Ruhrort. (Ingots, billets, slabs, plates and sections) (Dusselderf)

Area Mülheim. Steelworks Mülheim (Ingots, slabs and plates) (Dusseldorf)

Duisburg-Huttenheim. (Plates) (Dusseldorf)

Australian Iron & Steel, Pty., Ltd.,

Port Kembla, N.S.W. (Plates, bars, sections and forgings) (Port Kembla)

Steelworks, Kwinana, Western Australia. (Small bars and sections) (Fremantle)

d'Auxonne, Acieries & Fonderies, Auxonne (Côte d'Or), France. (Small castings) (PARIS)

Avesta Jernverks Aktiebolag, Avesta, Sweden. (Plates, sections and castings) (Stockholm)

Azuma Steel Casting Co. Ltd., Takaoka Works, Takaoka, Japan. (Castings) (Yоконама) Azuma Steel Works, Ltd.

Azuma Plant, Tokyo, Japan. (Ingots for plate) (Yokohama)

Senju Plant, Tokyo, Japan. (Rolling mills for plates) (Yоконама)

Babcock & Wilcox, Sociedad Espanola de Construcciones.

Head Office: Calle Ercilla 1, Bilbao, Spain.

Works: Galindo-San Salvador Del Valle, Vizcaya, Spain. (Castings, ingots and forgings) (BILBAO)

Bakker, N.V., Machinefabriek-Staalgieterij, Ridderkerk, Holland. (Ingots and castings) (ROTTERDAM)

Bergische Stahlindustrie K.G., Remscheid, Germany. (Castings) (Dusseldorf)

Bertoli S.p.A., Officine Fratelli Bertoli fu Rodolfo, Udine, Italy. (Castings, forgings, bars and sections) (TRIESTE.)

Bethlehem Steel Corporation,

Bethlehem, Pa., U.S.A. (Ingots, forgings, bars and sections) (Philadelphia)

Burns Harbour Plant, Chesterton, Indiana, U.S.A. (Rolling mills for plates) (Chicago)

Johnstown Plant, Johnstown, Pa., U.S.A. (Ingots, billets, slabs, plates and bars) (CLEVELAND)
Lackawanna, N.Y., U.S.A. (Ingots, blooms, billets,

Lackawanna, N.Y., U.S.A. (Ingots, blooms, billets, bars, plates and sections) (CLEVELAND, O.)

Labaron, Park J.S.A. (Polling mills for bars and

Lebanon, Pa., U.S.A. (Rolling mills for bars and rivets) (Philadelphia)
Los Angeles 54, Cal., U.S.A. (Round bars) (Los

Angeles)
Seattle Wash U.S.A. (Sections hars and narrow

Seattle, Wash., U.S.A. (Sections, bars and narrow flats) (SEATTLE)

Sparrows Point, Md., U.S.A. (Plates) (Baltimore) Steelton, Pa., U.S.A. (Castings) (Philadelphia)

Bhartia Electric Steel Co., Ltd., Calcutta, India. (Castings) (CALCUTTA)

Birdsboro Corporation, Birdsboro, Pa., U.S.A. (Castings) (PHILADELPHIA)

Bischoff-Werke K.G., Abt. Stahlgiesserei Ludinghausen/ Westphalia, Germany. (Castings) (DORTMUND)

Björneborgs Jernverks Aktiebolag, Björneborg, Sweden, (Ingots and forgings) (GOTHENBURG)

Black Clawson-Kennedy, Owen Sound, Ontario, Canada. (Castings) (Toronto)

Blanc-Misseron, Société Française des Aciéries de, Quievrechain, (Nord), France. (Ingots and castings) (VALENCIENNES)

Boel, Usines Gustave, Soc. An., La Louvière, Belgium. (Ingots, forgings, castings, plates and universal flats) (Antwerp)

Bofors, Aktiebolaget, Bofors, Sweden. (Ingots, forgings, castings and rolled bars) (GOTHENBURG)

Böhler, Gebr. & Co., Aktiengesellschaft, Vienna, Austria.

Works: Bohlerwerk, Low Austria. (Small forgings)
(VIENNA.)

Works: Bruckbach, Low Austria. (Rolling mills for sections and bars) (VIENNA)

Works: Kapfenberg, Styria. (Ingots, castings, forgings, bars and plates) (VIENNA)

Bolzano, S.p.A. Acciaierie di, Bolzano, Italy. (Ingots, billets, bars and forgings) (VENICE)

Boom, Travaux Métalliques de, Société Anonyme, Boom, Belgium. (Small castings) (ANTWERP)

Borsig A.G., Berlin-Tegel, Germany. (Ingots, forgings and castings) (BERLIN)

Boschgotthardshutte, Otto Breyer G.m.b.H., Edelstahlwerk-Press-u. Hammerwerk-Mechanische Werkstätten, Hüttental-Weidenau, Germany. (Ingots and forgings) (Cologne)

Boxholms A/B., Boxholm, Sweden. (Ingots, rolled slabs, blooms, billets, sections and bars) (Stockholm)

Bradford Kendall Ltd.

Works: Adelaide, South Australia. (Castings) (ADELAIDE)

Works: Alexandria, Sydney, N.S.W. (Castings) (Sydney, N.S.W.)

Works: Runcorn, Queensland. (Castings) (Brisbane.)

Works: South Beach, South Fremantle. (Castings)
(FREMANTLE)

Brasileira de Usinas Metalurgicas, Companhia, Usina de Neves, Sao Goncalo, Estado do Rio de Janeiro, Brazil. (Ingots, sections and bars) (RIO DE JANEIRO)

Breda Fucine S.p.A., Sesto San Giovanni, Milan, Italy. (Castings and forgings) (MILAN)

Breda Siderurgica Società per Azioni, Sesto San Giovanni, Milan, Italy. (Ingots and sections) (MILAN)

Breitenbach, Ed., G.m.b.H., Huttental-Weidenau/Sieg, Germany. (Castings) (Cologne)

Bremer Vulkan, Schiffbau und Maschinenfabrik, Bremen-Vegesack, Germany. (Castings) (Bremen)

Brescia, Acciaieria e Tubificio di, Società Anonima, Brescia, Italy. (Ingots, sections and bars and castings) (MILAN)

Broken Hill Proprietary Co., Ltd.

Iron & Steel Works, Newcastle, N.S.W. (Ingots, billets, plates, sections, strip and castings) (New-CASTLE, N.S.W.)

Iron & Steel Works, Whyalla, S. Australia. (Ingots, castings, bars and sections) (WHYALLA)

Bulten-Kanthal AB,

Kanthal-Divisionen, Hallstahammar, Sweden. (Ingots, billets, bars and castings) (STOCKHOLM)

Ramnäs Brukdivisionen, Ramnäs, Sweden. (Rolling mills for bars) (Stockholm)

Burlington Steel Company, Division of Slater Steel Industries, Ltd., Hamilton, Ontario, Canada. (Small sections and bars) (TORONTO)

Burmeister & Wain's Maskin-og Skibsbyggeri, Aktieselskabet, Copenhagen, Denmark. (Ingots, forgings and castings) (COPENHAGEN)

Burn & Co., Ltd., Howrah, India. (Castings) (CALCUTTA) C.A.E. Machinery Ltd., Vancouver, B.C. (Small castings) (Vancouver)

Caleotto, Acciaieria e Ferriera del, S.p.A., Lecco, Italy. (Ingots, castings, bars, small sections and small forgings) (MILAN)

- Cameron Iron Works Inc., Houston, Texas. (Ingots and forgings) (Galveston)
- Canada Forging Ltd., Welland, Ontario, Canada. (Forgings) (TORONTO)
- Canadian Steel Foundries Division Hawker Siddeley Canada Ltd., Longue Pointe, Montreal, P.Q., Canada. (Castings) (Montreal)
- Cantieri Navali del Tirreno e Riuniti, S.p.A., Ancona, Italy. (Small castings) (Venice)
 - Riva Trigoso, Genoa, Italy. (Small Forgings)
 (Genoa.)
- Carlo Tassara, Stabilimenti Electtrosiderurgioi S.p.A., Breno, Brescia, Italy. (Ingots and small forgings) (MILAN)
- Ceretti, Pietro Maria, S.p.A., Ferriera Dell'Ossola-Villadossola, Italy. (Castings) (MILAN)
- Charleroi, Société Anonyme de la Fabrique de Fer de, Charleroi, Belgium. (Ingots, slabs and plates) (Antwerp)
- Cheoy Lee Shipyard Lantau Island, Hong Kong. (Castings) (Hong Kong)
- Chiers, Société des Hauts-Forneaux de la, Forges de Vireux Molhain, Vireux, Ardennes, France. (Bars and sections) (VALENCIENNES)
- Christiania Spigerverk, Oslo, Norway. (Ingots and bars, also rivet bars) (Oslo)
- Chubu Steel Plate Co. Ltd., Nakagawa Works, Nagoya, Japan. (Ingots and plates) (Kobe)
- Clabecq, Société Anonyme Forges de, Clabecq, Belgium. (Ingots, plates, bars and sections) (ANTWERP)
- Cockerill-Ougrée-Providence S.A., Seraing, Belgium.
 - Group A Works: Division Centre, Ougrée. (Ingots, blooms, billets, slabs and thin plates) (ANTWERP)
 - Division Ouest, Seraing. (Ingots, blooms, billets, slabs, castings and forgings) (Antwerp)
 - Group B Works: Marchienne-au-Pont. (Sections, bars, ingots and blooms) (ANTWERP)
 - Group D Works: d'Hautmont, Nord France. (Ingots and sections) (Valenciennes)
- Colorado Fuel & Iron Corporation, Minnequa Works, Pueblo, Colorado, U.S.A. (Ingots, bars and small sections) (Chicago)
- "COMETNA" Companhia Metalurgica Nacional, S.A.R.L., Amadora, Portugal. (Castings) (LISBON)
- Combinatul Siderurgic Gheorghiu-Dej, Galatz, Rumania. (Plates) (GALATZ)
- Commonwealth Steel Co., Ltd., Lidcombe Works, Sydney, N.S.W. (Castings) (Sydney, N.S.W.) Waratah Works, Newcastle, N.S.W. (Castings, forgings, ingots and bars) (Newcastle, N.S.W.)
- Compagnie Générale des Aciers, Société Anonyme, Thy-le-Château, Belgium. (Castings) (ANTWERP)
- Companhia Ferro e Aco de Vitoria, Vitoria, State of Espirito Santo, Brazil. (Rolling mill for bars and sections) (RIO DE JANEIRO)

- Companhia Siderurgica Nacional, Volta Redonda, Usina Presidente Vargas, Estado do Rio de Janeiro, Brazil. (Plates and sections) (RIO DE JANEIRO)
- Companhia Siderurgica Paulista, Cosipa, Cubatao, Sao Paulo, Brazil. (Ingots and plates) (Santos)
- Compañia Auxiliar de Ferrocarriles, Beasain, Guipuzcoa, Spain. (Small castings and forgings) (BILBAO)
- Consolidated Mining & Smelting Co. of Canada Ltd., Trail, B.C., Canada. (Castings) (VANCOUVER)
- Cooperativa Industrial Electrodos y Aceros, Boó., Santander, Spain. (Castings) (BILBAO)
- Crane Fisa S.A., Bilbao, Spain. (Small castings) (Bilbao)
- Creusot Loire.
 - Division Mecanique Entreprises, Usines de St. Chamond 42-St. Chamond (Loire), France. (Forgings) (Paris)
 - Division Siderurgie, Usine du Marais, 42-Saint Etienne, France. (Plates) (Lyons)
 - Division Transformation, Usines de l'Ondaine, 42-Firminy (Loire), France. (Ingots, billets, blooms bars, castings and forgings) (Paris)
 - Usine de Pamiers, Pamiers, France. (Castings and forgings) (MARSEILLES)
 - Usine des Dunes, Malo les Bains (Nord), France.
 (Ingots, billets, blooms, bars and forgings)
 (DUNKIRK)
 - Usines d'Imphy-58, France. (Ingots, forgings, bars and sections) (Lyons)
- Creusot, Société des Forges et Ateliers du, (S.F.A.C.), Usines Schneider, Le Creusot, France. (Ingots, forgings, castings, plates and sections) (Lyons)
- Crucible Steel Company of Canada, Ltd., Sorel, P.Q., Canada. (Ingots and forgings) (MONTREAL)
- Crucible Steel Corporation, Midland Division, P.O. Box 226, Midland, Pa. 1505g., U.S.A. (Ingots, slabs, billets, hot rolled and cold drawn bars) (CLEVELAND, O.)
- Daido Steel Co., Ltd.
 - Chita Plant, Nagoya, Aichi Prefecture, Japan. (Ingots, billets and bars) (KOBE)
 - Hoshizaki Plant, Nagoya, Japan. (Ingots and bars) (Kobe)
 - Shibukawa Works, Shibukawa, Japan. (Ingots, small forgings and bars) (Yokohama)
 - Tsukiji Plant, Nagoya, Japan. (Ingots, forgings and castings) (Kobe)
- Daitetsu Steel Industrial Co. Ltd., Osaka, Japan. (Ingots and sections)
- Dalmine S.p.A. Head Office: Milan, Italy.
 Dalmine Costa Volpino, Bergamo. (Seamless tubes)
 (MILAN)
 - Dalmine Works, Bergamo. (Ingots and seamless tubes) (MILAN)

Danske, (Det), Staalvalsevaerk A/S, Frederiksvaerk, Denmark. (*Plates, sections and bars*) (Copenhagen) Date Seiko Co., Ltd., Tokyo, Japan. (*Castings*)

(Үоконама)

Davies & Baird Pty. Ltd., Newlands Road, Coburg, Melbourne, Australia. (Castings) (MELBOURNE)

Decker, Gebrüder, Betrieb 1, Eisen- & Stahlgiesserei, Nürnberg 2, Ostendstr. 84. (Electric steel castings) (Augsburg)

Deemer Steel Casting Co., New Castle, Delaware, U.S.A. (Castings) (PHILADELPHIA)

Dembiermont & Cie., Maurice, Hautmont (Nord), France. (Forgings) (VALENCIENNES)

Deusto, S.A., Talleres de, Luchana, Bilbao, Spain. (Ingots, castings and small forgings) (BILBAO)

Deutsche Edelstahlwerke A.G., Krefeld, Germany. (Ingots, forgings and rolled materials) (Dusseldorf) Dikkers, G., & Co., N.V., Hengelo, Holland. (Small

castings) (AMSTERDAM)

Dingler, Karcher & Cie., G.m.b.H., Saarbrücken-Saar. (Castings) (SAARBRÜCKEN-SAAR)

Dingler, Karcher & Cie., G.m.b.H., Saarländisches Stahlwerk, Worms/Rhein, Germany. (Castings) (Mannheim)

Dominion Foundries & Steel Ltd., Hamilton, Ontario, Canada. (Ingots, plates and castings) (TORONTO)

Dominion Steel & Coal Corporation Ltd.

Montreal Works, 5870, St. Patrick Street, Montreal, Canada. (Angles, bars and rivets) (MONTREAL)

Donegal Steel Foundry Company, 601, East Market Street, Marietta, Pa., U.S.A. (Castings) (PHILA-DELPHIA)

Drammens Jernstoberi & Mek-Verksted, A/S, Drammen, Norway. (Small castings) (OSLO)

Dunswart Iron & Steel Works, Ltd., Benoni, South Africa. (Castings, ingots, billets and small sections) (Vereeniging)

Duro-Felguera, Sociedad Metalúrgica, La Felguera, Asturias, Spain. (Castings) (GIJON)

Echevarria, Sociedad Anonima, Bilbao, Spain. (Small sections and bars, small forgings and ingots) (Bilbao)

Echeverria, Patricio, S.A., Legazpia, Spain. (Ingots, blooms, forgings and small bars) (Bilbao)

Edelstahlwerke Buderus A.G., Wetzlar, Germany. (Ingots, blooms, billets, bars forgings and plates) (Cologne)

Edelstahlwerk Witten A.G., Witten-Ruhr, Germany. (Ingots, billets, bars, forgings and narrow flats) (DORT-MUND)

Edgewater Corporation, Oakmont, Pennsylvania, U.S.A. (Ingots and forgings) (CLEVELAND)

Eguiluz, Talleres, Miranda del Ebro, Burgos, Spain. (Castings) (Bilbao)

Egyptian Iron & Steel Co., S.A.E., Helwan, U.A.R. (*Plates*) (ALEXANDRIA)

Eisen-und Stahlwerke Oehler & Co. A.G., Aanau, Switzerland. (Castings) (WINTERTHUR)

Eisen-und Stahlwerk Pleissner G.m.b.H., Herzberg/Harz, Germany. (Castings) (Hannover)

Eisenwerk Bohmer, Witten, Ruhr, Dortmund, Germany. (Castings) (DORTMUND)

Eisenwerk Geweke, R. & C. R. Lange K.G., Hagen-Haspe, Germany. (Electric steel castings) (DORTMUND)

Eisenwerk Rödinghausen K.G., Lendringsen Krs., Iserlohn, Germany. (Castings) (DORTMUND)

Electrosteel Castings Ltd., Khardah, West Bengal, India. (Castings) (CALCUTTA)

Ellerbrock, Hans, Stahlgiesserei und Maschinenfabrik, Hamburg, Germany. (Castings) (Hamburg)

Empire Steel Castings Inc., Reading, Pa., U.S.A. (Castings) (Philadelphia)

Empresa Nacional Bazan, El Ferrol del Caudillo, Spain. (Castings) (El Ferrol)

Empresa Nacional Siderurgica, S.A., (ENSIDESA), Avilés, Spain. (Ingots, slabs and billets for re-rolling, plates and sections) (GIJON)

Endo Iron Works Co. Ltd., Osaka, Japan. (Forgings) (Kobe)

Enterprise Engine & Foundry Co., South City, Cal., U.S.A. (Castings) (SAN FRANCISCO)

Eregli Demir ve Celik Fabrikalari T.A.S., Eregli, Turkey. (Ingots and plates) (ISTANBUL)

Eschweiler Bergwerks-Verein Hüttenbetriebe, Eschweiler-Aue, Germany. (Ingots and seamless tubes) (Cologne)

Esco Ltd., Port Coquitlam, B.C., Canada. (Castings)
(VANCOUVER)

Españoles, Astilleros, S.A.,

Factoria de Reinosa, Spain. (Ingots, forgings, castings, plates and sections) (BILBAO)

Factoria de Sestao. (Small castings, ingots and forgings) (Bilbao)

Esperance Longdoz S.A., Liege, Belgium. (Ingots and thin plates) (Antwerp)

Etablissement des Constructions et Armes Navales de Guerigny, Guerigny, France. (Ingots, bars, forgings and castings) (PARIS)

Euskalduna, Compania, Funicion de Asua, (near Bilbao,) Vizcaya, Spain. (Castings) (BILBAO)

Fagersta Bruks Aktiebolag, Fagersta, Sweden (Brukskoncernen).

Works: Fagersta. (Blooms, billets, forgings, rolled bars and electric resistance welded tubes) (Stock-HOLM)

Works: Forsbacka. (Blooms, billets, forged and rolled bars) (Stockholm)

Works: Osterbybruk. (Castings, forgings and rolling mill for bars) (Stockholm)

Faggian, Acciaierie Elettriche Pio, Soc. per Azioni, La Spezia, Italy. (Small castings) (La Spezia)

Falck, Acciaierie e Ferriere Lombarde. Head Office & Works: Milan, Italy. (Weldless rolled or drawn tubes) (Milan)

"Concordia". Works: Sesto San Giovanni. (Ingots and plates) (MILAN)

- "Unione". Works: Sesto San Giovanni. (Ingots, sections, bars, forgings and castings) (MILAN)
- Falk Corporation, Milwaukee, Wis., U.S.A. (Castings) (CHICAGO)
- Ferretera Montanesa S.A., Torrelavega, Spain. (Castings) (BILBAO)
- Ferry-Capitain S.A.R.L., Usines de Bussy-Joinville, France. (Electric steel castings) (Paris)
- Feurs, Fonderies & Acieries Electriques de, Feurs, Loire, France. (Small castings) (MARSEILLES)
- FIAT, Società per Azioni, Sezione Ferriere Piemontesi, Turin, Italy. (Ingots, plates, sections, also seamless and welded tubes) (Genoa)
- Finkl, A., & Sons Company, Chicago, Ill., U.S.A. (Forgings) (Chicago)
- Fischer, George, Ltd., Schaffhausen, Switzerland. (Castings) (WINTERTHUR)
- Fit Ferrotubi-Fabbrica Italiana Tubi Ferrotubi, Italy. (Ingots, billets and weldless rolled and drawn tubes) (Genoa)
- Fives-Lille-Cail, Société de.
 - Usine de Fives, Lille (Nord), France. (Forgings)
 (VALENCIENNES)
 - Usine de Denain, Denain (Nord), France. (Castings, ingots, forgings, blooms, bars and sheets) (Valenciennes)
- Flag S.p.A. Marcon (Mestre). (Small castings) (Venice) Fomas-Forgiatura Moderna Acciai Speciali S.p.A., Osnago, (Como), Italy. (Forgings) (Milan)
- Fonderia Acciaieria Giovanni Mandelli, Turin, Italy. (Castings) (GENOA)
- Fonderie de Fer et d'Acier, Biel, Switzerland. (Castings) (Winterthur)
- Fonderies Grandry, S.A., Mohon (Ardennes), France. (Castings) (VALENCIENNES)
- Fonderies Meridionales, Marseilles, France. (Castings) (MARSEILLES)
- Forjas Alavesas S.A., Vitoria, Spain. (Ingots, rolled bars and forgings) (BILBAO)
- Frichs A/S, Aarhus, Denmark. (Castings) (Aalborg)
- Fried. Krupp Huttenwerke A.G., Bochum, Germany.
 Works: Bochum. (Ingots, plates, forgings, castings and bars) (Dusseldorf)
 - Works: Rheinhausen. (Ingots, bars and sections)
 (Dusseldorf)
- Friedrich-Carl-Hütte G.m.b.H., Delligsen über Alfeld/ Leine, Germany. (Castings) (HANNOVER)
- Fucine Meridionali, S.p.A., Bari, Italy. (Castings and forgings) (NAPLES)
- Fukushima Seiko Co., Ltd., Fukushima, Japan. (Castings) (Yоконама)
- Funabashi Steel Works Ltd., Funabashi City, Chiba Prefecture, Japan. (Ingots and flat bars) (Yoko-HAMA)
- Funderia, S.A. de, Manresa, Spain. (Castings) (BARCELONA)
- Fundiciones Arriaran S.A., Lazcano, Guipuzcao, Spain-(Castings) (Bilbao)

- Fundiciones del Estanda, S.A., Beasain, Spain. (Castings) (BILBAO)
- Fundiciones Echevarria S.A., Beasain, Guipuzcoa, Spain. (Ingots, small rolled bars and castings) (Bilbao)
- Fundiciones Especiales Zaragoza, S.A., Zaragoza, Spain. (Castings) (Bilbao)
- Fundicoes do Rossio de Abrantes, S.A.R.L., Rossio de Abrantes, Portugal. (Castings) (LISBON)
- Fundidora de Fierro y Acero de Monterrey, S.A., Monterrey, N.L., Mexico. (*Plates*) (Tampico)
- Ganz-Mavag Mozdony Vagon es Gepgyar, Budapest, Hungary. (Castings and forgings) (VIENNA)
- General Metals Corporation, Oakland, Cal., U.S.A. (Castings) (San Francisco)
- Generale d'Hydraulique et de Mecanique Usine Metallurgique de Marquise, Rinxent, Pas de Calais, France. (Castings) (Dunkirk)
- Gennevilliers, Aciéries de, Gennevilliers, Seine, France. (Castings) (PARIS)
- Go Iron Works, Ltd., Tarui Works, Tarui, Japan. (Small castings) (Kobe)
- Gottwald, Leo, Werk Hattingen, Ruhr, Germany. (Small forgings) (DORTMUND)
- Granite City Steel Co., Granite City, Ill., U.S.A. (CHICAGO)
- Great Lakes Steel Corporation, Division of National Steel Corporation, Ecorse, Detroit 29, Michigan, U.S.A. (Ingots, billets, bars, slabs, plate, blooms, sheet and coiled strip) (CLEVELAND)
- Gresele, Acciaierie Valbruna di Ernesto, Vicenza, Italy. (Castings, bars, sections and forgings) (Venice)
- Grossmann, C., Eisen-und Stahlwerk A.G., Solingen-Wald, Germany. (Castings) (Dusseldorf)
- Gueugnon, Forges de, Gueugnon, (S & L), France. (Rolling mill for plates) (PARIS)
- Guivisa S.A., Basauri, Bilbao, Spain. (Castings) (Bilbao)
- Gussstahlwerk Carl Bönnhoff, Wetter/Ruhr, Germany. (Ingots and castings) (Dortmund)
- Gussstahlwerk Risch K.G., Bergisch-Gladbach, Germany. (Electric steel castings) (Cologne)
- Gussstahlwerk Wittman A.G., Hagen-Haspe, Germany. (Castings) (DORTMUND)
- Gutehoffnungshütte Sterkrade A.G., Werk Sterkrade, Oberhausen-Sterkrade, Germany. (Forgings) (DUSSEL-DORF)
- Hadfields Steel Works, Ltd., Alexandria, Sydney, N.S.W. (Castings and forgings) (SYDNEY)
- HADIR, Société des Haut-Fourneaux et Aciéries de Differdange-St.Ingbert-Rumelange, DifferdangeWorks, Luxembourg. (Sections and bars) (SAARBRÜCKEN)
- Hainaut-Sambre, Société Métallurgiques, S.A., Couillet, Belgium.
 - Division de Couillet. (Ingots, blooms, bars, forgings and castings) (ANTWERP)
 - Division de Montignies et Chatelineau. (Rolling mill) (ANTWERP)

LLOYD'S REGISTER OF SHIPPING

Haine St. Pierre et Lesquin, Aciéries de, Société Anonyme, Haine St. Pierre, Belgium. (Castings) (Antwerp) Lesquin-lez-Lille (Nord), France. (Castings) (Valen-

Hakodate Dock Co., Ltd., Hakodate Shipyard, Hakodate, Japan. (Small forgings and castings) (Yоконама)

Hallstahammar Aktiebolag, Hallstahammar, Sweden. (Bars) (Stockholm)

Haneda Pipe Works Co., Ltd., Tokyo, Japan. (Seamless tubes) (Yоконама)

Hatakeyama Iron Works Co., Ltd., Komatsugawa Works, Tokyo, Japan. (Small forgings) (Yоконама)

Hawker Siddeley Canada Ltd., Trenton Works, Trenton, N.S. (Forgings) (HALIFAX, N.S.)

Heavy Engineering Corp., Ltd., Foundry Forge Plant, P. O. Dhurwa, Ranchi, India. (Castings) (JAM-SHEDPUR)

Helsingors Skibsvaerft-og Maskinbyggeri A/S, Aktieselskabet, Elsinore, Denmark. (Forgings and castings) (Copenhagen)

Henricot, Usines Emile, Court St. Etienne, Belgium. (Castings) (ANTWERF)

Herchamet S.A.I.C., Fundicion Electrica de Aceros) Velez Sarfield, Rosario, Argentina. (Castings (BUENOS AIRES)

Hierros y Aceros Industriales S.A., San Adrian de Besos, Barcelona, Spain. (Small castings) (BARCELONA)

Hindustan Steel Ltd.

Rourkela, Orissa, India. (Ingots, slabs and plates) (CALCUTTA)

Durgapur Steel Plant, West Bengal, India. (Blooms, billets, bars and sections) (CALCUTTA)

Bhilai Steel Project, Bhilai, Madhya Pradesh, India. (Ingots, blooms, billets and sections) (CALCUTTA)

d'Hirson S.A., Aciéries, Hirson, Aisne, France. (Castings) (VALENCIENNES)

Hitachi, Ltd.

Hitachi Works, (Yamate Factory), Hitachi-shi, Japan. (Castings) (Yokohama)

Kasado Works, Kudamatsu, Japan. (Castings and forgings) (Shimonoseki)

Katsuta Works, Katsutashi, Ibaragi-ken, Japan. (Ingots, forgings and castings) (Yоконама)

Hitachi Metals, Ltd.

Yasugi Works, Yasugi, Japan. (Ingots, bars and forgings) (Kobe)

Tobata Works, Tobata, Japan. (Castings) (Shimonoseki)

Hitachi Shipbuilding & Engineering Co., Ltd.

Chikko Shipyard, Osaka, Japan. (Ingots, castings and forgings) (Kobe)

Innoshima Shipyard, Innoshima, Japan. (Forgings and small castings) (Kobe)

Hoesch Hüttenwerke, A.G., Dortmund, Germany.
Werk Phoeuix Hörde, Dortmund-Hörde. (Ingots, plates and castings) (Dortmund)

Werk Union, Dortmund. (Bars and sections) (DORTMUND)

Werk Westfalenhütte, Dortmund. (Ingots, billets, plates, bars and sections) (DORTMUND)

Hoganas A/B, Hoganas, Sweden. (Castings) (Helsing-Borg)

Hokuriku Kogyo Co., Ltd., Sanjo Plant, Sanjo, Niigata Přefecture, Japan. (Small forgings) (Yоконама)

Howa Machinery, Ltd., Inazawa Plant, Aichi Prefecture, Japan. (Castings) (Kobe)

Hubner-Vamag, Vereinigte Armaturenfabriken, Aktiengesellschaft, Vienna, Austria. (Castings) (VIENNA)

Hults Bruk A.B., Aby, Sweden. (Castings) (Stock-HOLM)

Huta 1 Maja, Gliwice, Poland. (Ingots and forgings) (KATOWICE)

Huta Baildon, Katowice, Poland. (Ingots, forgings and bars) (KATOWICE)

Huta Batory, Chorzow-Batory, Poland. (Forgings, plates and tubes) (KATOWICE)

Huta Bierut, Czestochowa, Poland. (Seamless tubes)
(Katowice)

Huta Bobrek, Bytom, Poland. (Ingots, slabs and blooms) (KATOWICE)

Huta im. M. Buczka, Sosnowiec, Poland. (Seamless tubes) (Katowice)

Huta Dzierzynski, Dabrowa Gornicza, Poland. (Billets, sections and bars) (KATOWICE)

Huta Florian, Swietochlowice, Poland. (Angles and bars) (KATOWICE)

Huta Jednosc, Siemianowice Slaskie, Poland. (Ingots and seamless tubes) (Katowice)

Huta Kosciuszko, Chorzow, Poland. (Billets, blooms, sections and rivet bars) (KATOWICE)

Huta Labedy, Labedy, Poland. (Flats and sections) (Katowice)

Huta im. Lenina, Krakow, Poland. (Ingots, slabs, plates up to 12 mm) (KATOWICE)

Huta Malapanew, Ozimek k/Opola, Poland. (Castings) (Katowice)

Huta Nowotko, Ostrowiec Swietokrzyski, Poland. (Sections) (Katowice)

Huta Pokoj, Ruda Slaska, Poland. (Plates, sections and small forgings) (KATOWICE)

Huta Stalowa Wola, Stalowa Wola, Poland. (Castings, forgings, plates and sections) (Katowice)

Huta Warszawa, Warsaw, Poland. (Ingots, forgings and rolled bars) (Katowice)

Huta Zawiercie, Zawiercie, Poland. (Flats and bars) (KATOWICE)

Hüttenwerk Oberhausen A.G., Oberhausen, Germany. (Ingots, plates, sections and bars) (Dusseldorf)

Indian Iron & Steel Co., Ltd.

Burnpur Works, Burnpur, West Bengal, India. (Sections and angles) (CALCUTTA)

Kulti Iron Works, Kulti, India. (Castings) (CAL-CUTTA) Indian Tube Company Ltd., Jamshedpur, India. (Seamless tubes) (CALCUTTA)

Industrias del Besos, S.A., Barcelona, Spain. (Small sections and bars) (Barcelona)

Industrias Mecanicas, Sociedad Anonima, Barcelona, Spain. (Castings) (BARCELONA)

Industrija Masina i Livnica, Tuzla, Yugoslavia. (Castings) (Split)

Inland Steel Co., Indiana Harbor, Ind., U.S.A. (Ingots, blooms, billets and slabs) (Chicago)

Interprovincial Steel and Pipe Corporation Ltd., Regina, Saskatchewan, Canada. (*Plates*) (TORONTO)

Ishikawajima-Harima Heavy Industries Co., Ltd., Aioi Works, Aioi, Japan. (Castings and forgings) (Kobe)

Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan. (Ingots, forgings and castings) (Yokohama)

"ITALSIDER" S.p.A., Head Office: Via Corsica 4, Genoa, Italy.

S.I.A.C., Genoa. (Ingots, forgings, plates and castings) (Genoa)

Stabilimento di Lovere. (Sections, bars, castings and forgings) (MILAN)

Stabilimento di Marghera. (Rolling mills for small sections and bars) (Venice)

Stabilimento di Portovecchio di Piombino. (Ingots, blooms, sections and bars) (Leghorn)

Stabilimento di Taranto. (Ingots, slabs and plates) (Naples)

Oscar Sinigaglia Works, Genoa-Cornigliano. (Ingots, slabs and plates) (Genoa)

"ITALSIDER" S.p.A. Centro Siderurgico di Bagnoli, Naples. (Ingots, sections and bars) (NAPLES)

Izuo Chukosho Co., Ltd., Osaka, Japan. (Castings) (Kobe)

Jadot, Société Anonyme Etablissements, Beloeil, Belgium. (Small castings) (Antwerp)

Japan Casting and Forging Corporation, Tobata-ku, Kitakyshu City, Fukuoka Prefecture, Japan. (Forgings and castings) (NAGASAKI)

Japan Drop Forge Co., Ltd., Amagasaki, Japan. (Small forgings) (Kobe)

Japan Iron-Sand Steel Co. Ltd., Shikama Works, Himeji, Japan. (Ingots bars and sections) (Kobe)

Japan Special Steel Co., Ltd., Tokyo, Japan. (Ingots, forgings, blooms, billets and bars) (YOKOHAMA)

Japan Steel Works Ltd.

Hiroshima Works, Hiroshima, Japan. (Forgings and castings) (Shimonoseki)

Muroran Works, Muroran, Japan. (Ingots, forgings, castings and plates) (YOKOHAMA)

Jemappes, Société Anonyme Forges et Laminoirs de, Jemappes, near Mons, Belgium. (Ingots, blooms and bars) (Antwerp)

Joban Machinery Co. Ltd., Uchigo Factory, Fukushima Prefecture, Japan. (Castings) (Yоконама) Jonan Iron Works Co., Ltd., Haneda Works, Tokyo, Japan. (Small forgings) (YOKOHAMA)

Jones & Laughlin Steel Corporation, Pittsburgh, Pa., U.S.A. (CLEVELAND, O.)

Jorgensen, Earle, M. Co., Forge Division, Seattle, Washington. (Seattle)

K.G.M.-Altalanos Gepipari Igazgatosag, Budapest, Hungary.

Works: Öntödei Vallalat 1. sz., Gyára, Budapest. (Castings) (Vienna)

K.G.M. Jármuipari Igazatóság, Budapest, Hungary. Works: Magyar Vagon-és Gépgyár, Györ. (Castings) (VIENNA)

K.G.M. Vaskohászati Igazgatóság, Budapest, Hungary.

Works: Lenin Kohászati Müvek, Miskole-Diósgyör. (Ingots, slabs, sections, bars, castings and forgings) (Vienna)

Works: Dunai Vasmü, Dunaujváros. (Ingots, slabs and plates) (Vienna)

Works: Dunai Vasmü, Lörinci Hengermüve, Budapest. (Rolling mill for plates) (VIENNA)

Works: Ozdi Kohászati üzemek, Ozd. (Ingots, slabs, plates, sections and bars) (Vienna)

K.K. Teikoku Kokan Seizosho, Osaka, Japan. (Seam-less tubes) (Kobe)

Kaiser Steel Corporation, Fontana, Cal., U.S.A. (Ingots and plates) (Los Angeles)

Kakegawa Endo Iron Works Co., Ltd., Kakegawa, Japan. (Forgings) (Yоконама)

Kansai Steel Corp., Sakai, Japan. (Ingots, bars and flat bars) (Kobe)

Kansai Tekko Co., Ltd., Amagasaki, Japan. (Small forgings) (Kobe)

Kanto Special Steel Works, Ltd., Fujisawa, Kanagawa Pref., Japan. (Forgings) (Yоконама)

Kawaguchi Kinzoku Kogyo Kabushiki Kaisha, Kawaguchi, Japan. (Castings) (Үоконама)

Kawasaki Heavy Industries Ltd.

Crushing Plant Mfg. Division, Japan. (Castings) (Yokohama)

Hyogo Cast Steel Works, Kobe. (Castings) (Kobe) Kobe Works, Kobe. (Castings) (Kobe)

Kawasaki Steel Corporation.

Chiba Works, Chiba. (Slabs and plates) (Yоконама) Chita Works, Handa City. (Ingots and castings) (Кове)

Fukiai Works, Kobe. (Blooms and sections) (Kobe)

Mizushima Works, Mizushima, Japan. (Ingots, forgings, castings, bars, plates and sections) (Kobe)

Kilby Steel Co., Furnace Division, Anniston, Alabama, U.S.A. (Ingots) (MOBILE)

Kinka Kikai Co., Ltd., Gifu, Japan. (Castings) (KOBE)

Klafreströms Bruk, A/B., Klavreström, Sweden. (Small castings) (Gothenburg)

Klinger, Rich., Aktiengesellschaft, Gumpoldskirchen, near Vienna, Austria. (Small castings) (VIENNA)

Klöckner-Werke A.G.

Works: Hütte Bremen, Germany. (Plates) (Bremen)
Works: Hütte-Haspe, Hagen-Haspe, Germany.
(Rolling mills for bars) (Dortmund)

Works: Huttenwerke Georgsmarienhutte, Germany. (Ingots and bars) (Hannover)

Works: Mannstaedt-Werke, Troisdorf, Germany. (Rolling mills for sections) (COLOGNE)

Works: Osnabruck, Germany. (Forgings and castings) (Hannover)

Knorr-Bremse G.m.b.H., Volmarstein-Schmandbruch, Germany. (Castings) (DORTMUND)

Kobe Steel Ltd.

Works: Amagasaki, Japan. (Ingots, sections and bars) (Kobe)

Works: Kakogawa Plant, Kakogawa City, Hyogo Prefecture, Japan. (Ingots and plates) (KOBE)

Works: Kobe, Japan. (Ingots, blooms, billets, bars castings and seamless tubes) (Kobe)

Works: Takasago Plant, Takasago, Japan. (Ingots, forgings and castings) (Kobe)

Kockums Jernverk, Kallinge, Sweden. (Ingots and castings) (Malmo)

Kohlswa Jernverks Aktiebolag. (Ingots, forgings and castings) (Stockholm)

Kokko Steel Works, Ltd., Osaka, Japan. (Ingots, bars and castings) (Kobe)

Kokoku Steel Casting Co., Ltd., Osaka, Japan. (Castings) (Kobe)

Komatsu Ltd.

Awazu Plant, Komatsu, Japan. (Castings) (Kobe)

Osaka Plant, Hirakata, Osaka Prefecture, Japan. (Castings) (Kobe)

Koninklijke Demka Staalfabrieken N.V., Utrecht, Holland. (Rolling mill for bars) (Amsterdam)

Koninklijke Nederlandsche Hoogovens & Staalfabrieken N.V. (Royal Netherlands Blast-furnaces & Steel Works, Ltd.), Ymuiden, Holland. (*Plates and sections*) (Amsterdam)

Kotobuki Industries Co., Ltd., Hiro Works, Kure, Japan. (Castings) (Hiroshima)

Krauss-Maffei A.G., München-Allach, Germany. (Castings) (Augsburg)

Kruiner Gussstahlwerk, Gevelsberg, Germany. (Castings) (Dortmund)

Kubota Ltd., Hirakata Plant, Hirakata, Osaka, Japan. (Castings) (Kobe)

Kumardhubi Engineering Works Ltd., P.O. Box Kumardhubi, Dist. Dhanbad, (Bihar), India. (Castings) (CALCUTTA)

Kureha Seiko Co. Ltd., No. 1 5-Chome Takeshima-Cho, Nishiyodogawa-Ku, Osaka, Japan. (Castings) (KOBE)

Kurimoto Iron Works Ltd., Kagaya Factory, Osaka, Japan. (Castings) (KOBE)

Latrobe Forge & Spring, Inc. Latrobe, Pa., U.S.A. (Ingots and forgings) (CLEVELAND, O.)

Lebanon Steel Foundry, Lebanon, Pa., U.S.A. (Small castings) (Philadelphia)

Leonard-Giot, Société Anonyme Usines & Aciéries, Marchienne-au-Pont, Belgium. (Castings) (ANTWERP)

Letson & Burpee, Ltd., Richmond, British Columbia, Canada. (Small castings) (VANCOUVER)

Llodio, S.A., Aceros de, Llodio, near Bilbao, Spain. (Castings, ingots, forgings and rolled bars) (Bilbao)

Los Angeles Steel Casting Co., Los Angeles, Cal., U.S.A. (Castings) (Los Angeles)

Luigi Giudici, Societa per Asioni, Rescaldina, Milan, Italy. (Small castings) (MILAN)

Lukens Steel Company, Coatesville, Pa., U.S.A. (Plates) (PHILADELPHIA)

Luzuriaga, Victorio, S.A., Pasajes, Guipuzcoa, Spain. Works: Usurbil, Guipuzcoa. (Castings) (Bilbao)

Lynn Macleod Metallurgy Ltd., Thetford Mines, P.Q., Canada. (Castings) (MONTREAL)

Maekawa Electric Steel Castings Co.

Osaka, Japan. (Castings) (KOBE)

Tobata Factory, Kitakyushu, Japan. (Castings) (Shimonoseki)

Maizuru Jukogyo Ltd., Maizuru, Japan. (Small castings) (Kobe)

Makine ve Kimya Endustri, Celik Fabrikasi, Kirikkale, Turkey. (Ingots, forgings, rolled sections and bars) (ISTANBUL)

Mangolds Engineering, Port Elizabeth, South Africa. (Small castings) (Durban)

Manitoba Rolling Mills Division of Dominion Bridge Co., Ltd., Selkirk, Manitoba, Canada. (Billets, bars and sections) (Montreal)

Mannesmann A.G. Huttenwerke, Duisburg-Huckingen. (Ingots, slabs and bars) (Dusseldorf)

Mannesmannrohren-Werke G.m.b.H., Dusseldorf. (Seamless and welded tubes) (Dusseldorf)

Manoir-Pompey, Acieries du, 27 Pitres, France. (Castings) (ROUEN)

Marathon Argentina, Aceros Finos y Especiales S.A., Villa Constitucion, Santa Fe, Argentina. (Ingots, forgings and forged bars) (Buenos Aires)

Maritime Steel and Foundries, Ltd., New Glasgow, Nova Scotia. (Small castings) (HALIFAX, N.S.)

- Marrel Frères, Société Anonyme des Etablissements, Usine des Etaings, near Rive-de-Gier (Loire), France. (Ingots, plates and bars) (MARSEILLES)
- Mason & Cox, Pty. Ltd., Adelaide, S. Australia. (Castings) (ADELAIDE)
- Material y Construcciones S.A., Barcelona, Spain. (Castings) (BARCELONA)
- Matsuya Kogyo Co., Ltd., Fukuoka, Japan. (Small forgings) (Shimonoseki)
- Maubeuge, Société Anonyme de la Fabrique de Fer de, Louvroil (Nord), France. (Ingots) (VALENCIENNES)
- Maximilianshütte, Eisenwerk-Gesellschaft m.b.H., Sulzbach-Rosenberg, Bavaria, Germany. Haidhof Works: (Ingots, billets, bars, small sections and thin plates) (Augsburg)
- Meridionali, Acciaierie e Tubificio, S.p.A., Bari, Italy. (Castings and weldless rolled or drawn tubes) (NAPLES)
- Metal & Steel Factory, Ishapore, West Bengal, India. (Ingots, blooms, billets, forgings, castings and bars) (Calcutta)
- Metallurgica Marcora S.n.C., Busto Arsizio (Varese), Italy. (Weldless rolled and drawn tubes) (MILAN)
- Metalurgica Duarte Ferreira S.A.R.L., Tramagal, Portugal. (Castings) (LISBON)
- Meuse, Les Acieries de la, S.A., Cheratte-lez-Liege, Belgium. (Seamless tubes) (Antwerp)
- Meuse, Les Usines à Tubes de la, Flémalle-Haute, Belgium. (Seamless and welded tubes) (Antwerp)
- Meuse, Société Métallurgique de la, Forges et Aciéries de Stenay, Stenay, Meuse. (Castings) (VALENCIENNES)
- Meyer, F., Stahl-, Draht- und Rohrenwerke, Dinslaken, Germany. (Ingots, billets for tubes and bars) (Dussel-Dorf)
- Midvale-Heppenstall Company, Nicetown, Philadelphia, Pa., U.S.A. (Forgings) (PHILADELPHIA)
- Miniere et Metallurgique de Rodange S.A., Rodange, Luxembourg. (Sections) (Saarbrücken)
- Mitsubishi Heavy Industries Ltd., Yokohama Shipyard and Engine Works, 1-1 Midoricho, Nishi-Ku, Yokohama, Japan. (Castings) (Yоконама)
 - Hiroshima Works, Hiroshima, Japan. (Ingots, castings and small forgings) (Shimonoseki)
 - Kobe Shipyard & Engine Works, Kobe, Japan. (Ingots, small forgings and castings) (Kobe)
 - Mihara Machinery Works, Mihara, Japan. (Castings and forgings) (Kobe)
 - Nagasaki Works, Nagasaki, Japan. (Castings) (Nagasaki)
 - Takasago Machinery Works, Takasago, Japan. (Forgings) (KOBE)
- Mitsubishi Metal Mining Co., Ltd., Okegawa Plant, Saitama Prefecture, Japan. (Small castings) (Yoконама)
- Mitsubishi Steel Manufacturing Co., Ltd., Tokyo, Japan. Hirota Works, Fukushima Pref. (Castings) (Yоконама)
 - Nagasaki Works, Nagasaki, Japan. (Ingots, blooms, plates, forgings and castings) (Nagasaki)

- Tokyo Steel Works. (Billets, bars and small forgings) (YOKOHAMA)
- Mitsui Miike Machinery Co., Ltd., Miike Works, Omutashi, Japan. (Castings) (Shimonoseki)
- Mitsui Shipbuilding & Engineering Co., Ltd., Japan.
 - Fujinagata Works, Osaka, Japan. (Forgings) (Kobe)
 - Tamano Works, Tamano, Japan. (Ingots, forgings and castings) (Kobe)
- Mitsumoto Valve Manufacturing Co., Ltd., Domyoji, Osaka, Japan. (Small forgings and small castings) (Kobe)
- Miyazaki Iron Works Co., Ltd., Osaka, Japan. (Small forgings) (Kobe)
- Motala Verkstad, A/B, Motala Verkstad, Sweden. (Ingots and castings) (GOTHENBURG)
- Mukand Iron & Steel Works, Ltd., Kurla, Bombay, 70, India. (Castings) (BOMBAY)
- Nagasaki Metal Industries Association, Kaizu-Machi, Isahaya-shi, Nagasaki, Japan. (Small forgings) (Nagasaki)
- Nakayama Steel Products Co. Ltd., Tsurumi Works, Tsurumi, Yokohama, Japan. (Ingots and plates) (YOKOHAMA)
- Nakayama Steel Works Ltd., Osaka, Japan. (Ingots and plates) (Kobe)
- National Forge Co.
 - Erie Division, Erie, Pennsylvania, U.S.A. (Ingots, forgings and castings) (CLEVELAND, O.)
 - Irvine, Warren County, Pennsylvania, U.S.A. (Ingots and forgings) (CLEVELAND, O.)
- National Iron & Steel Co., Ltd., Stephen House, Calcutta, 1, India. (Castings) (CALCUTTA)
- National Iron & Steel Mills Ltd., Jalan Besi Baja, Jurong Industrial Estate, Singapore. (Small sections and bars) (Singapore)
- Nazionale "Cogne", S.p.A. Head Office: Turin. Works: Aosta. (Ingots, blooms, billets and bars) (Genoa)
- Neunkircher Eisenwerk A.G., Neunkirchen/Saar, Germany.
 - Neunkirchen Works. (Ingots, bars and sections)
 (SAARBRÜCKEN)
 - Homburg Works. (Ingots and seamless tubes)
 (Saarbrücken)
- Newport News Shipbuilding & Dry Dock Co., Newport News, Va., U.S.A. (Castings and forgings) (Newport News)
- Nicolacopoulos, G., & Co., Athens, Greece, Steelworks at Eleusis. (Castings) (Piræus)
- Niederrheinische Hutte, A.G., Duisburg, Germany. (Rolling mill for narrow flats and sections) (Dusselder)
- Nippon Chuzo Kabushiki Kaisha, Kawasaki, Japan. (Castings) (Yokohama)
- Nippon Kokan Kabushiki Kaisha. Asano Dockyard, Yokohama, Japan. (Small forgings) (Yоконама)

Fukuyama Iron Works, Fukuyama, Japan. (Ingots, sections, blooms and plates) (Kobe)

Keihin Iron Works. (YOKOHAMA)

Mizue Plant. (Plates up to 12,5 mm in thickness)

Tsurumi Plant. (Ingots and plates)

Tubular & Structural Products Dept. (Tubes, bars and sections)

Nippon Sharyo Seizo Kaisha, Ltd., Nagoya, Japan. (Castings) (Kobe)

Nippon Stainless Steel Co., Ltd., Naoetsu Works, Niigata, Japan. (Ingots, forgings, castings and plates) (YOKOHAMA)

Nippon Steel Corporation.

Engineering, Machinery and Foundry Division, Tobata, Kitakyushu, Japan. (Castings and forgings) (Shimonoseki)

Hirohata Works, Himeji City, Japan. (Ingots, billets, plates and sections) (Kobe)

Kamaishi Works, Kamaishi, Japan. (Sections and bars) (Yokohama)

Kimitsu Works, Kimitsu, Japan. (Ingots and plates) (YOKOHAMA)

Muroran Works, Hokkaido, Japan. (Billets, sections and bars) (Yоконама)

Nagoya Works, Nagoya, Japan. (Ingots, plates and electric resistance welded tubes) (Kobe)

Sakai Works, Sakai, Osaka, Japan. (Ingots, sections and thin plates) (Kobe)

Tobata Area Works, Japan. (Ingots and plates) (Shimonoseki)

Tokyo Works, Japan. (Rolling mills for weldless, rolled or drawn tubes) (YOKOHAMA)

Yawata Area Works, Japan. (Plates, sections, ingots and forgings) (Shimonoseki)

Nippon Steel Foundry Co., Ltd., Osaka, Japan. (Castings) (KOBE)

Nippon Yakin Kogyo Co., Ltd., Kawasaki, Japan. (Ingots, forgings, bars and thin plates) (Yоконама)

Nisshin Steel Works, Ltd., Kure Works, Kure, Japan.
(Ingots, blooms, billets and strip) (Shimonoseki)

Nittoku Metal Industry Co., Ltd., Tokyo, Japan. (Small forgings) (YOKOHAMA)

Nordische Stahlwerke, Bach & Co., Neumünster, Germany. (Castings) (KIEL)

Nordiska Armaturfabrikerna, A/B, Linköping, Sweden. (Castings) (Sтоскноім)

Norrbottens Järnverk Aktiebolag, Lulea, Sweden. (Ingots, slabs, blooms and billets, bars and sections) (Stockholm)

Norsk Jernverk, A/S., Mo-i-Rana, Norway. (Electric steel ingots, billets, sections and bars) (OSLO)

Nová huť Klementa Gottwalda, národni podnik (New Metallurgical Works of Klement Gottwald, National Corporation), Ostrava-Kunčice, Czechoslovakia. (Ingots) (Vienna) Nueva Montana Quijano S.A., Nueva Montana, Santander, Spain. (Castings) (Bilbao)

Oesterreichisch-Alpine Montangesellschaft, Vienna.

Works: Donawitz, Styria. (Sections and strip)
(VIENNA)

Works: Kindberg, Styria. (Rolling mills for small sections, bars and strip) (Vienna)

Works: Traisen, Low Austria. (Castings) (VIENNA)

Ohio Steel Foundry Co., Lima, Ohio, U.S.A. (Ingots, forgings and castings)

Oji Steel Co., Ltd.,

Gunma Plant, Gunma Pref., Japan. (Ingots and bars) (Yоконама)

Kita-Ku, Tokyo, Japan. (Flat bars) (Yokohama)

Okamoto Iron Works Co., Kobe, Japan. (Forgings) (Kobe)

Okano Valve Manufacturing Co., Ltd., Moji. Works: Yukuhashi, Japan. (Small castings and small forgings) (Shimonoseki)

Olarra S.A.

Works: Erandio, Bilbao Spain. (Ingots and small bars) (BILBAO)

Works: Larrondo, Lujúa, Vizcaya, Spain. (Ingots and rolled bars) (Bilbao)

Olympic Steel Works, Seattle, Wash., U.S.A. (Castings) (SEATTLE)

Onomichi Anchor Manufacturing Co., Ltd., Onomichi, Japan. (Castings) (Kobe)

Orion S.p.A., Porto Industriale, Trieste, Italy. (Forgings and castings) (TRIESTE)

Osaka Chain & Machinery Manufacturing Co., Ltd., Kaizuka Works, Osaka, Japan. (Small castings) (Kobe)

Osaka Shipbuilding Co., Ltd., Taira Steel Works, Taira City, Fukushima Prefecture, Japan. (Castings) (Yоконама)

Osaka Steel Casting Co., Ltd., Osaka, Japan. (Small castings) (Kobe)

Osaka Steel Tube Co., Ltd., Sasebo Works, Sasebo, Japan. (Seamless tubes) (NAGASAKI)

Oxelosunds Jarnverk, Oxelosund, Sweden. (Ingots, rolled slabs and plates) (STOCKHOLM)

Oy Fiskars Ab Salon Konepaja Salo, Finland. (Small castings) (ÅBO)

Ozuki Seikosho, Ltd., Shimonoseki, Japan. (Castings) (Shimonoseki)

Pacific Metals Company Limited.

Naoetsu Factory, Naoetsu, Niigata, Japan. (Ingots and castings) (Yokohama)

Toyama Factory, Toyama City, Japan. (Ingots and forgings) (YOKOHAMA)

Pacific States Steel Corporation, Union City, Cal., U.S.A. (Ingots, sections and bars) (SAN FRANCISCO)

Pacific Steel Castings Co., Berkeley, Cal., U.S.A. (Castings) (SAN FRANCISCO)

Pacifico, Compañía de Acero del, S.A., Talcahuano, Chile. (Ingots, plates, bars and sections) (VALPARAISO)

Paderwerk Gebr. Benteler, Schlossneuhaus, Germany. (Seamless tubes) (DORTMUND)

Paris et d'Outreau, Aciéries de, Société Anonyme, Usine d'Outreau, Pas de Calais, France. (Castings) (DUNKIRK)

Paris-Seine, Fonderies et Aciéries de, Usine de la Folie, Avenue de Bobigny, Noisy le Sec (Seine), France. (Castings) (Paris)

Penn Steel Castings Co., Chester, Pa., U.S.A. (Castings) (Philadelphia)

Pennsylvania Forge, Division of Chemetron Corporation, Tacony, Philadelphia, 35, Pa., U.S.A. (Forgings) (Philadelphia)

Pennsylvania Steel Foundry and Machine Company, Hamburg, Pa., U.S.A. (Castings) (Philadelphia) Phoenix Steel Corporation.

Works: Claymont, Delaware, U.S.A. (Plates) (Philadelphia)

Works: Structural Division, Phoenixville, Pa., U.S.A. (Sections, bars and rotary forged seamless tubes) (Philadelphia)

Pittsburgh Steel Company, Pittsburgh 30, Pa., U.S.A.

Works: Monessen, Pa. (Ingots, billets and slabs)

(CLEVELAND, O.)

Works: Allenport, Pa. (Rolling mills) (CLEVE-LAND, O.)

Pohlig-Heckel-Bleichert, Vereinigte Maschinenfabriken A.G., Abt. Stahlformgiesserei, Werk Heckel, Rohrbach/Saar, Germany. (Castings) (Saarbrücken-Saar)

Pont A Mousson, Société des Fonderies de, Usine de Fumel, France. (Castings, centrifugal cast pipes) (Marselles)

Porter, H. K. (France) Acieries Division Marpent, Marpent (Nord), France. (Castings) (VALENCIENNES)

Provence S.A., Fonderies et Aciéries de, Marseilles, France. (Castings) (Marseilles)

Quaker Alloy Casting Co., Myerstown, Pa., U.S.A. (Small castings) (Philadelphia)

Raahe Oy, Raahe, Finland. (Small castings) (ÅBO)

Rauma Repola Oy, Lokomon Tehtaat, Tampere, Finland. (Ingots, forgings and castings) (ÅBO)

Rautaruukki Oy, Raahe, Finland. (Ingots and plates) (ÅBO)

Republic Steel Corporation, Cleveland, O., U.S.A. Alabama City, Ala., U.S.A. (Mobile, Ala.)

Buffalo Plant, Buffalo, N.Y., U.S.A. (CLEVELAND, O.)

Central Alloy District, Massillon Plant, Massillon, O., U.S.A. (CLEVELAND, O.)

Chicago Plant, Chicago, Ill., U.S.A.

Works: 118th Street, Chicago. (Rolling mills)
East Chicago, Ind. (Angles and bars) (CHICAGO)

Cleveland District, Cleveland, O., U.S.A. (CLEVE-LAND, O.)

Corrigan McKinney Plant. (Ingots, blooms and billets)

Upson Nut Plant. (Round and square bars)

Youngstown District, Youngstown, O., U.S.A. (CLEVELAND, O.)

Rheinstahl Giesserei A.G., Gussstahlwerk Gelsenkirchen. (Castings) (DUSSELDORF)

Rheinstahl Giesserei A.G., Gussstahlwerk Oberkassel, Dusseldorf-Oberkassel, Germany. (Ingots and castings) (Dusseldorf)

Rheinstahl Hüttenwerke, A.G.

Werk Friedrich Wilhelms-Hütte, Mulheim und Meiderich, Germany. (Castings) (Dussel-Dorf)

Henrichshütte, Hattingen-Ruhr. (Ingots, plates, forgings and eastings) (DORTMUND)

Riken Tanzo Co., Ltd., Maebashi Plant, Maebashi, Japan. (Small forgings) (YOKOHAMA)

Rikimi Cast Steel Co., Ltd., Osaka, Japan. (Small castings) (Kobe)

Rohrenwerke Bous G.m.b.H., Bous/Saar, Germany. (Seamless tubes) (SAARBRUCKEN)

Rosenlew, Oy W., A/B, Porin Konepaja, Pori, Åbo. (Small castings) (ÅBO)

Rotterdamsche Droogdok Maatschappij, Rotterdam, Holland. (Ingots, forgings and small castings) (ROT-TERDAM)

Rudarsko - Metalurski Kombinat - Zenica, Zeljezara Zenica, Zenica, Yugoslavia. (Billets, bars, sections and forgings) (Split)

Rudnici I Zelezara Smederevo, Smederevo, Yugoslavia. (Small castings) (Split)

Rudnici I Zelezarnica, "Skopje", Skopje, Yugoslavia. (Plates) (Split)

S.A.F.A.S.—Societa Azionaria Fonderia Acciai Speciali, Tavernelle di Altavilla Vicentina (Vicenza), Italy. (Castings) (VENICE)

S.A.F.A.U. Ferriere Acciaierie di Udine, Udine, Italy. (Ingots, forgings, blooms, bars and sections) (Trieste)

Safog, S.A., Fonderie Officine di Gorizia, Gorizia, Italy. (Castings) (TRIESTE)

Sambre et Meuse, Société Anonyme des Usines et Aciéries de.

Usines de Feignies, Feignies (Nord), France. (Castings) (VALENCIENNES)

Usines de Saint Brieuc (Côtes-du-Nord), France. (Small castings) (NANTES)

Sande Giesserei, Sande-Oldenburg, Germany. (Castings) (EMDEN)

Sandvikens Jernverks Aktiebolag, Sandviken, Sweden. (Ingots, forgings and tubes) (Stockholm)

Sanyo Special Steel Co., Ltd., Himeji, Japan. (Ingots, forgings and rolled bars) (KOBE)

Sasebo Heavy Industries Co., Ltd., Sasebo, Japan. (Ingots, forgings and castings) (NAGASAKI)

Saut-du-Tarn, Société Nouvelle Du, 81-Saint-Juery, France. (Castings) (MARSEILLES)

Scaw Metals, Ltd., Union Junction, Transvaal, S. Africa. (Rivet bars, small rolled sections and castings) (VereenIGING)

Schmidt & Clemens, Edelstahlwerk, Kaiserau b/Engelskirchen, Bez. Köln, Germany. (Ingots, forgings, castings and bars) (Cologne)

Schoeller-Bleckmann Stahlwerke A.G., Vienna.

Works: Muerzzuschlag-Hoenigsberg, Styria. (Bars)
(Vienna)

Works: Ternitz, Low Austria. (Castings, forgings and bars) (Vienna)

Schutte, Meyer & Co., G.m.b.H., Letmathe, Westphalia, Germany. (Small castings) (DORTMUND)

Seo Koatsu Kogyo Co., Ltd., Osaka, Japan. (Small forgings) (Kobe)

Sharon Steel Corporation, Roemer Works, Farrell, Pa., U.S.A. (Ingots, blooms, billets, narrow plates and sections) (CLEVELAND)

Shimizu Kotetsu Co., Ltd., Tokyo, Japan. (Forgings) (YOKOHAMA)

Shin Nippon Tanko K.K., Kawasaki, Japan. (Small forgings) (Yоконама)

Shun Fung Ironworks Ltd., Kowloon, Hong Kong. (Castings) (Hong Kong)

Siderurgia Nacional, S.a.r.l., Seixal, Portugal. (Sections and bars) (LISBON)

Siderurgica Ebroacero S.A., Zaragoza, Spain. (Castings)
(Bilbao)

S.I.F.E.M.A. S.A., Bilbao, Spain. (Steel castings)

S.I.S.M.A. — Società Industrie Siderurgiche Meccaniche & Affini, Villadossola (Novara), Italy. (Rolled bars and rivets) (MILAN)

SKF. Stål Hofors Bruk, Hofors, Sweden. (Billets, bars and forgings, and thick walled tubes) (Stockholm)

Škoda, Oborový Podnik, Plzeň, Czechoslovakia. (Castings and forgings) (Vienna)

Smedjebackens Valsverks Aktiebolag, Smedjebacken, Sweden. (Bars, sections and ingots for re-rolling)

Société Anonyme d'Exploitation des Aciéries de Bordeaux, Pessac, Gironde, France. (Castings) (BORDEAUX)

Société des Aciers Fins de l'Est, F-57 Hagondange, France. (Ingots, blooms, billets, bars, plates and sheets) (Saar)

Société Lorraine de Laminage Continu, Sollac, B.P.11, Florange, Moselle, France. (Ingots, slabs and plates) (SAAR)

Société Métallurgique de Normandie, Mondeville, France. (Ingots, blooms, billets and bars) (ROUEN)

Société Nouvelle des Acieries de Pompey. (Ingots, blooms, billets, plates, angles and round bars) (Paris)

Sollinger Hütte G.m.b.H., Uslar/Solling, Germany. (Castings) (HANNOVER)

Sorel Industries, Ltd., Sorel, P.Q., Canada. (Ingots and forgings) (MONTREAL)

South African Iron & Steel Industrial Corporation, Ltd., "Iscor" Works, Pretoria, Transvaal, S. Africa. (Ingots, billets sections and forgings) (VEREENIGING) "Iscor" Works, Vanderbijlpark, Transvaal, S. Africa. (Ingots, billets, slabs and plates) (VEREENIGING)

Staalgietwerk SMDK, N.V. Utrecht. (Ingots and castings)
(Amsterdam)

Stahl-u. Röhrenwerke Reisholz G.m.b.H., Germany. Works at Reisholz. (Ingots and seamless tubes)

Stahlwerke Bochum A.G., Bochum, Germany. (Castings, rolled materials and plates) (Dusseldorf)

Stahlwerk Mannheim A.G., Mannheim-Rheinau, Germany. (Castings) (MANNHEIM)

Stahlwerk Peine-Salzgitter A.G., Werke Peine, Germany. (Ingots, billets, sections and bars) (Hannover)

Stahlwerke Peine-Salzgitter A.G., Werk Salzgitter, Salzgitter-Drutte, Germany. (Ingots, plates, bars and sections) (Hannouer)

Stahlwerke Rohling-Burbach G.m.b.H.

Works: Burbach. (Ingots, billets, and sections)
(Saarbrucken)

Works: Völkungen. (Castings, ingots, billets, bars and forgings) (Saarbrucken)

Stahlwerk Südwestfalen, A.G.

Werk Geisweid, Geisweid Kreis Siegen, Germany.
(Ingots, bars, billets, thin plates, sheets and coils)
(COLOGNE)

Werksgruppe Geisweid, Works Nieder-Schelden, Germany. (Ingots and slabs) (Cologne)

Werksgruppe Hagen, Werk Wehringhausen, Hagen, Germany. (Ingots, bars and forgings) (DORT-MUND)

Standard Steel Division of Baldwin-Lima-Hamilton Corp., Burnham, Pa., U.S.A. (Forgings) (PHILA-DELPHIA)

Stavanger Staal A.S., Jørpeland, near Stavanger, Norway. (Castings) (BERGEN)

Steel Company of Australia, Pty. Ltd., Coburg, Melbourne, Australia. (Castings) (Melbourne)

Steel Company of Canada, Hamilton, Ontario, Canada.

Works: Hamilton. (Bars and angles, plates and billets) (TORONTO)

Works: Montreal. (Bars, angles, plates and billets)
(Montreal)

Steelplast, S.A., La Louvière, Belgium. (Small castings)
(Antwerp)

Steirische Gusstahlwerke, A.G., Vienna. Works: Judenburg, Styria, Austria. (Forgings and bars) (VIENNA)

Stenberg, John, Oy-AB, Helsingfors, Finland. (Small castings) (Helsinki/Helsingfors)

Stora Kopparbergs Bergslags A/B, Specialstalverken, Vikmanshyttan, Sweden. (Forgings, bars and sections) (STOCKHOLM) Stora Kopparbergs Bergslags Aktiebolag, Falun, Sweden.

Works: Domnarfvet. (Ingots, sections and plates)
(Stockholm)

Works: Söderfors. (Forgings, bars and sections)
(Stockholm)

Stork-Volma N.V., Gorredijk, Holland. (Small castings) (Haren-Groningen)

Stramezzi, P., & C., Acciaieria e Ferriera di Crema, Crema, Italy. (Ingots, bars, small sections and rivets) (MILAN)

Streicher, M., Asperg/Württ, near Stuttgart, Germany. (Castings) (Stuttgart)

Stridsberg & Biorck, A.B., Trollhattan, Sweden. (Castings) (Gothenburg)

Strömmen Staal A/S, Norway.

Works: Raufoss. (Castings) (Oslo) Strommen. (Castings) (Oslo)

Sucesora de Aceros Electricos S.A., Barcelona, Spain. (Castings) (Barcelona)

Sud Ouest, Société des Forges et Aciéries du, Bordeaux (Gironde), France. (Castings and forgings) (BORDEAUX)

Sulzer Bros. Ltd., Winterthur, Switzerland. (Castings and forgings) (WINTERTHUR)

Sumitomo Electric Industries, Ltd., Itami Works, Itami, Hyogo Prefecture, Japan. (Ingots and small bars) (Kobe)

Sumitomo Metal Industries, Ltd.

Kashima Steel Works, Kashima (Plates) (Yоконама)

Kokura Steel Works, Kitakyushu-City, Japan. (Ingots, billets, bars and sections) (Shimonoseki) Osaka Steel Works, Osaka. (Castings, forgings and bars) (Kobe)

Steel Tube Works, Amagasaki, Japan. (Ingots, forgings, small bars, sections and seamless tubes.) (Kobe)

Wakayama Steel Works, Wakayama, Japan. (Ingots, plates, seamless tubes and electric resistance welded tubes) (Kobe)

Sumitomo Shipbuilding & Machinery Co., Ltd.

Niihama Works, Niihama, Japan. (Castings) (Kobe)

Tamashima Works, Tamashima, Japan. (Castings) (Kobe)

Sunnan Iron Works Co., Ltd., Yaizu, Japan. (Forgings) (Yokohama)

Surahammars Bruks Aktiebolag, Surahammar, Sweden. (Plates, forgings and castings) (Stockholm)

Svedala-Arbra Aktiebolag, Svedala, Sweden. (Castings) (Malmo)

Svenska Jarnvagsverkstaderna, A/B, Linköping, Sweden. (Castings) (Sтоскноьм)

Svenska Kullagerfabriken, A/B.

Works: Katrineholm, Sweden. (Castings) (STOCK-HOLM)

Works: Hellefors Jernverk, Hällefors, Sweden. (Ingots and bars) (Gothenburg)

Švermové Železiarné, Narodny Podnik (Sverma's Iron Works, National Corporation), Podbrezová, Czechoslovakia. (Ingots, and plates) (Vienna)

Sydney Steel Corporation, Sydney, N.S., Canada. (Ingots, billets and sections) (HALIFAX, N.S.)

Tagajo Steel Castings Co. Ltd., Tagajo, Miyagi Prefecture, Japan. (Castings) (Yоконама)

Takada Steel Works, Ltd., Takada City, Nara Prefecture, Japan. (Castings) (Kobe)

Takasaki Metal Industry Co., Ltd., Takasaki Plant, Takasaki, Japan. (Small castings) (Yоконама)

Talleres de Moreda, S.A., Gijon. (Forgings) (GIJON)

Tamaris, Société des Ateliers et Fonderies de, Tamaris (Gard), France. (Castings) (MARSEILLES)

Tata Engineering & Locomotive Co., Ltd., Jamshedpur 4, India. (Castings) (CALCUTTA)

Tata Iron & Steel Co., Ltd., Jamshedpur, India. (Blooms, billets, bars, plates and sections) (CALCUTTA)

Teikoku Steel Casting Co., Ltd., Osaka, Japan. (Castings) (Kobe)

Temple, Acieries du, Saint-Michel de Maurienne, (Savoie) France. (Rolled and forged bars and billets) (Lyons)

Tennessee Coal & Iron Division, United States Steel Corporation, Birmingham, Ala., U.S.A. Works: Ensley, Ala. Rolling mills, also forgings: Bessemer and Fairfield, Ala. (MOBILE)

"Terni" Società per l'Industria e l'Elettricità. Works: Terni, Italy. (Ingots, forgings, castings and plates) (Naples)

Titovi Zavodi Litostroj, Ljubljana, Yugoslavia. (Castings) (Split)

Tohoku Special Steel Works Ltd., Sendai, Japan. (Ingots, small forgings, billets and bars) (Yоконама)

Tokai Special Steel Co., Ltd., Nagoya, Japan. (Ingots) (Kobe)

Tokushu Seiko (Special Steel Mfg.) Co., Ltd., Kawasaki Works, Kawasaki, Japan. (Ingots, forgings and bars) (Yоконама)

Tokyo Kikai Kabushiki Kaisha, Oshima Cast Steel Works, Tokyo, Japan. (Castings) (Yоконама)

Tokyo Precision Forging Works Co., Ltd. (Tokyo Seitan Works Co., Ltd.), Ichikawa City, Chiba Prefecture, Japan. (Small forgings) (Yоконама)

Tokyo Steel Casting Co., Ltd., Tokyo, Japan. (Castings) (Yоконама)

Tokyo Tankosho Co., Ltd., Kawasaki Factory, Kawasaki, Japan. (Small forgings) (Yоконама)

Topy Industries Ltd.

Toyohashi Works, Toyohashi, Japan. (Ingots, sections and flat bars) (Kobe)

Toshin Steel Co., Ltd.

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Himeji Works, Himeji, Japan. (Rolled sections and bars) (Kobe)

Tokyo Steel Works, Tokyo, Japan (Sections and ingots for forging and plates) (Yokohama)

Tosi, Franco, Società per Azioni, Legnano, Italy. (Forgings and castings) (MILAN)

Toyo Kikai-Kinzoku Co. Ltd., Tsuchiyama Plant, Akashi, Japan. (Small castings and small forgings) (Kobe)

Třinecké železárny velké Rijnové socialistické revoluce, národni podnik (Třinec Iron Works Great-Socialistic October Revolution National Corporation), Třinec, Czechoslovakia. (Ingots, sections, bars and castings) (VIENNA)

Trubia, Fábrica Nacional de, Trubia Asturias, Spain. (Castings and forgings) (GIJON)

Tsurumi Steel Tube Co., Ltd., Yokohama, Japan. (Seamless and welded tubes) (YOKOHAMA)

Turkiye Demir ve Celik Isletmeleri, Karabuk, Turkey (Ingots, thin plates, rolled sections and bars) (ISTANBUL)

Tvornica Dizalica I. Ljevaonica "Vulkan", Rijeka II, Yugoslavia. (Castings) (RIJEKA)

Tweer, Reinhard, G.m.b.H., Sennestadt/Westf., Germany. Works: Sennestadt. (Castings) (Hannover)

Ube Industries, Ltd., Ube Machinery Works, Ube, Japan. (Ingots, forgings and castings) (Shimonoseki)

Uddeholms Aktiebolag, Uddeholm, Sweden.

Works: Degerfors. (Ingots, plates, sections and bars) (Gothenburg)

Works: Hagfors, (Castings, ingots, forgings, bars and sections) (Gothenburg)

Works: Nykroppa. (Ingots) (Gothenburg)

Works: Storfors. (Seamless tubes) (Gothenburg)

Ugine Kuhlmann, Savoie, France. (Ingots, billets, bars, sections, castings and forgings. (MARSEILLES)

União Fabril, Companhia, Barreiro, Portugal. (Castings) (LISBON)

Union de Siderurgicas, Asturianas, S.A. (UNINSA).
Fabrica de Mieres, Asturias, Spain. (Sections, bars

and plates up to 15 mm. in thickness) (GIJON)
Fabrica de Gijon, Gijon, Spain. (Rivet bars and castings) (GIJON)

Factoria de La Felguera, La Felguera, Asturias, Spain.
(Ingots, billets, plates and sections) (Gijon)

Union des Aciéries, Société Anonyme, Marcinelle, Charleroi, Belgium. (Castings) (ANTWERP)

Union Sidérurgique du Nord et de l'Est de la France, "USINOR".

Usine de Dunkerque, Dunkerque (Nord). (Ingots and plates) (DUNKERQUE)

GROUPE A.

Usines de Denain, Denain (Nord). (Ingots, thin plates and sections) (VALENCIENNES)

GROUPE B.

Usines de Valenciennes, Valenciennes (Nord).
(Ingots, forgings, blooms, bars and sections)
(VALENCIENNES)

GROUPE C.

Usine de Longwy (Meurthe et Moselle), France. (SAAR)

Section Mont Saint Martin. (Sections and plates)
Section Senelle. (Ingots, blooms, bars and sections)
Usine de Thionville, Thionville (Moselle), France.

(Forgings and castings) (SAAR)

Union Steel Corporation of South Africa, Ltd. (Usco).

Works: Vereeniging, Transvaal, South Africa.

(Ingots, billets, small sections, castings and rivet bars) (Vereeniging)

Unitcast Division of Midland-Ross of Canada Limited, Sherbrooke, Quebec. (Castiugs) (MONTREAL)

United Engineers (Singapore) Pte. Ltd., Kampong Bahru Foundry. (Castings) (Singapore)

United States Steel Corporation, Pittsburgh, Pa., U.S.A.
Clairton Works, Clairton, Pa. (Ingots, blooms, bars and sections) (CLEVELAND, O.)

Duquesne Works, Duquesne, Pa. (Ingots, billets, blooms and bars) (CLEVELAND, O.)

Fairless Works, Fairless Hills, Pa. (Thin plates, bars and sections) (PHILADELPHIA)

Gary Works, Gary, Ind. (Billets, blooms, plates, sections, bars and forgings) (CHICAGO)

Geneva Works, Provo, Utah. (Plates) (Los Angeles)

Homestead District Works, Pa., including McKees Rock Works. (Ingots, billets, blooms, slabs, plates, sections and forgings) (CLEVELAND, O.)

Irvin Works, Dravosburg, Pa. (Rolling mills for thin plates) (CLEVELAND, O.)

McDonald Mills, Youngstown. (Rolling mills for bars and sections) (CLEVELAND, O.)

Ohio Works, Youngstown. (Ingots, billets and blooms) (CLEVELAND, O.)

South Works, South Chicago, Ill. (Plates, sections and bars) (CHICAGO)

Torrance Works, Torrance, Calif. (Round bars and sections) (Los Angeles)

Usinas Siderurgicas de Minas Gerais S.A., Belo Horizonte, Estado de Minas Gerais, Brazil.

Works: Ipatinga, Estado de Minas Gerais. (Ingots, slabs and plates) (Rio de Janeiro)

Válcovny Trub a Železarny, Narodni Podnik, (Tube Rolling Mills and Iron Works, National Corporation), Chomutov, Czechoslovakia.

Works: Železárny Bílá Cerkev, Narodni Podnik, Hrádek u Rokycan. (Ingots and bars) (Vienna) Works: Chomutov. (Seamless steel tubes) (Vienna) VALLOUREC.

Usine d'Anzin-Anzin (Nord), France. (Weldless rolled or drawn tubes) (VALENCIENNES)

Usine d'Aulnoye, Aulnoye (Nord), France. (Weldless rolled and drawn tubes) (VALENCIENNES)

Varde Staalvaerk, Varde, Denmark. (Ingots and castings) (ODENSE)

VEB Magdeburger Armaturenwerke, "Karl Marx", Magdeburg, Germany. (Castings) (Berlin)

VEB Maschinenfabrik und Eisengiesserei Dessau, Dessau, Germany. (Castings) (Berlin) VEB Schwermaschinenbau-Kombinat "Ernst Thalman", Magdeburg-Buckau, Germany. (Ingots and forgings) (Berlin)

VEB Qualitats - und Edelstahl - Kombinat Stahl - und Walzwerk Groditz, 8402 Groditz, Germany. (Forgings and castings) (Berlin)

Vecor Heavy Engineering, Ltd., Vanderbijlpark, Transvaal, South Africa. (Castings) (Vereeniging)

Vereinigte Oesterreichische Eisen-und-Stahlwerke, A.G-Works: Liezen, Styria. (Ingots for forgings, castings) (VIENNA)

Works: Linz a.d. Donau, Upper Austria. (Plates, forgings and castings) (VIENNA)

Vickers Hadwa Pty., Ltd., Perth, W. Australia. (Castings) (Fremantle)

Vickers Ruwolt Pty., Ltd., Richmond, Melbourne, Australia. (Steel castings and ingots) (Melbourne)

Victoria Machinery Depot Co., Ltd., Victoria, B.C., Canada. (Castings) (VANCOUVER)

Villa, Giovanni, S.p.A., Officine Meccaniche-Fucinati-Stampati, Milan, Italy. (Forgings) (MILAN)

Viomichania Chalyvon Ltd., Athens, Greece. (Castings) (Piræus)

Vitkovické Železárny Klementa Gottwalda, národni podnik (The Vitkovice Steel Works Klement Gottwald, National Corporation), Ostrava 10, Czechoslovakia. (Castings, forgings, plates, sections, bars and seamless tubes) (Vienna)

Vizcaya, Altos Hornos de, S.A., Fabrica de Sagunto, Sagunto, Spain. (Ingots, plates, bars and sections) (VALENCIA)

Vizcaya, Sociedad Altos Hornos de, Bilbao, Spain. (Ingots, bars, sections, forgings and plates up to 10 mm thick) (Bilbao)

Von Roll A.-G., Gerlafingen, Switzerland. (Ingots, round bars and forgings) (WINTERTHUR)

Vuoksenniska AB, Oy, Imatra Steel Works, Imatra, Finland. (Ingots, slabs, blooms and billets, bars, sections and castings) (Helsinki Helsingfors)

Waagner-Biro Aktiengesellschaft, Vienna, Austria.

Works: Werk C, Vienna. (Castings) (Vienna)

Wakamatsu Sharyo Co., Ltd., Kitakyushu-City, Japan. (Small castings) (Shimonoseki)

Walkers Ltd., Maryborough, Queensland, Australia. (Forgings and castings) (BRISBANE)

Walworth Aloyco International S.p.A. Stabilimento di Napoli, Naples. (Castings) (Naples)

Wartsila Oy, A/B, Steel Mill, Dalsbruk, Finland. (Ingots, billets, bars, castings and forgings) (ÅBO)

Washington Iron Works, Seattle, Wash., U.S.A. (Castings) (SEATTLE)

Wasino Machine Co., Ltd.,

Imamura Plant, Anjo Aichi Prefecture, Japan. (Castings) (Kobe)

Komaki Plant, Komaki Aichi Prefecture, Japan. (Small castings) (Kobe)

Watanabe Steel Works Co., Ltd., Tokyo, Japan. (Castings) (Yоконама)

Welmet Industries Ltd., Welland, Ontario, Canada. (Castings) (TORONTO)

Wendel-Sidélor.

Usine de Fenderie-Platinerie. F-57 Hayange, France. (Plates) (SAAR)

Usine Hagondange, F-57 Hagondange, France. (Blooms, billets, bars and sections) (SAAR)

Usine de Micheville, Villerupt, Meurthe et Moselle, France. (Ingots, blooms, billets, bars and sections) (SAAR)

Usine Orne-Amont, F-54 Homecourt/France. (Ingots, blooms, billets, narrow plates and universal flats). (SAAR)

Usine de Rombas, F-57 Rombas, France. (Ingots, blooms, billets, bars and sections) (SAAR)

Usine de St. Jacques F-57 Hayange. (Sections)

Western Canada Steel Ltd., (Vancouver Rolling Mills Ltd.,) Vancouver, B.C., Canada. (Sections and bars) (Vancouver)

Wittener Hutte Aktiengesellschaft Witten, Ruhr, Germany. (Castings) (DORTMUND)

Wood, Alan, Steel Company, Conshohocken, Pa., U.S.A. (Blooms, billets and plates) (Philadelphia)

Wurth, Société Anonyme des Anciens Etablissements Paul, Luxembourg. (Castings) (SAAR)

Yamato Kogyo Co., Ltd., Himeji, Japan. (Castings) (Kobe)

Yamato Steel Works, Ltd., Osaka, Japan. (Ingots, sections and plates) (Kobe)

Yonago Steel Works, Ltd., Yonago, Japan. (Castings) (Kobe)

Youngstown Sheet and Tube Company.

Brier Hill Works, Youngstown, Ohio, U.S.A.

Campbell Works, Campbell, Mahoning Co., Ohio, U.S.A. (Ingots, and plates up to 12,5 mm in thickness) (Pittsburgh)

Zakłady Mechaniczne Im. Gen. K. Swierczewskiego, Elblag, Poland. (Castings) (Gdansk)

Zaklady Metalurgiczne, Poznan, "Pomet" Poznan, ul Krancowa 15, Poland. (Gastings) (GDANSK)

Zaklady Urzadzen Chemicznych i Armatury Przemyslowej, Kielce, Poland. (Castings) (KATOWICE)

Zaklady Urzadzen Technicznych "Zgoda", Swietochlowice, Poland. (Forgings) (Katowice)

Združeno Podjetje Slovenke Zelezarne, Zelezarna, Jesenice, Jesenice, Yugoslavia. (*Plates, bars sections and castings*) (SPLIT)

Zelezarna Ravne, Ravne na Koroskem, Yugoslavia. (Castings, forgings, billets and bars) (RIJEKA)

Zelezárny a drátovny Bohumin, národni podnik (Iron Works and Wire Works Bohumin, National Corporation), Bohumin, Czechoslovakia. (Small sections and bars) (VIENNA)

Zeljezara "Boris Kidric", Niksic, Yugoslavia. (Plates and castings) (Split)

Zeljezara Sisak, Sisak-Predgradje, Yugoslavia. (Seamless tubes) (RIJEKA)

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APPENDICES TO CHAPTERS P AND Q

FIRMS IN COUNTRIES OTHER THAN GREAT BRITAIN AND IRELAND (ARRANGED ACCORDING TO SURVEYING DISTRICTS)

Aalborg

Frichs A/S, Aarhus, Denmark. (Castings)

Abo

Ky Åminnefors Kb, Åminnefors Stålverk, Åminnefors, Finland. (Ingots, billets, bars and sections)

Oy Fiskars Ab Salon Konepaja Salo, Finland. (Small castings)

Raahe Oy, Raahe, Finland. (Small castings)

Rauma Repola Oy, Lokomon Tehtaat, Tampere, Finland. (Ingots, forgings and castings)

Rautaruukki Oy, Raahe, Finland. (Ingots and plates)

Rosenlew, Oy W., Ab, Porin Konepaja, Pori, Finland. (Small castings)

Wärtsilä Oy, AB., Steel Mill, Dalsbruk, Finland. (Ingots, billets, bars, forgings and castings)

Adelaide

Bradford Kendall Ltd., Adelaide, South Australia. (Castings)

Mason & Cox Pty. Ltd., Adelaide, S. Australia. (Castings)

Alexandria

Egyptian Iron & Steel Co., S.A.E., Helwan, U.A.R. (*Plates*)

Amsterdam

Dikkers, G., & Co., N.V., Hengelo, Holland. (Small castings)

Koninklijke Demka Staalfabrieken, N.V., Utrecht, Holland. (Rolling mill for bars)

Koninklijke Nederlandsche Hoogovens & Staalfabrieken N.V. (Royal Netherlands Blast-Furnaces & Steel Works, Ltd.), Ymuiden, Holland. (*Plates and sections*)

Staalgietwerk SMDK, N.V., Utrecht, Holland. (Ingots and castings)

Antwerp

Allard, Usines & Aciéries, Société Anonyme, Mont-sur-Marchienne, near Charleroi. (Castings)

Allard, Usines & Aciéries, Société Anonyme, Turnhout. (Small castings)

Baume, Société Anonyme des Forges et Laminoirs de, Haine St. Pierre. (Ingots, bars and sections)

Boël, Usines Gustave, Soc. An., La Louvière. (Ingots, forgings, castings, plates and universal flats)

Boom, Travaux Métalliques de, Société Anonyme, Boom. (Small castings)

Charleroi, Société Anonyme de la Fabrique de Fer de, Charleroi. (Ingots, slabs and plates)

Antwerp—continued

Clabecq, Société Anonyme Forges de, Clabecq, Belgium. (Ingots, plates, bars and sections)

Cockerill-Ougrée-Providence, S.A., Seraing, Belgium.

Group A Works: Division Centre Ougrée. (Ingots, blooms, billets, slabs and thin plates)

Group B Works: Marchienne-au-Pont. (Sections, bars, ingots and blooms)

Division Ouest, Seraing. (Ingots, blooms, billets, slabs, castings and forgings)

Compagnie Générale des Aciers, Société Anonyme, Thy-le-Château, Belgium. (Castings)

Esperance Longdoz S.A., Liége, Belgium. (Ingots and thin plates)

Hainaut-Sambre, Société Métallurgiques, S.A., Couillet.
Division de Couillet. (Ingots, blooms, bars, forgings and castings)

Division de Montignies et Chatelinlau. (Rolling mill)

Haine St. Pierre et Lesquin, Aciéries de, Société Anonyme, Haine St. Pierre. (Castings)

Henricot, Usines Emile, Court St. Etienne. (Castings)

Jadot, Société Anonyme Etablissements, Beloeil,

Belgium. (Small castings)

Jemappes, Société Anonyme Forges et Laminoirs de, Jemappes, near Mons, Belgium. (Ingots, blooms and bars)

Leonard-Giot, Société Anonyme Usines & Aciéries Marchienne-au-Pont. (Castings)

Meuse, Les Aciéries de la, S.A., Cheratte-lez-Liege, Belgium. (Castings)

Meuse, Les Usines à Tubes de la, Flémalle-Haute, Belgium. (Seamless and welded tubes).

Steelplast, S.A. La Louvière, Belgium. (Small castings)
Union des Aciéries, Société Anonyme, Marcinelle,
Charleroi. (Castings)

Augsburg

Decker, Gebrüder, Betrieb 1, Eisen- & Stahlgiesserei, Nürnberg 2, Ostendstr. 84. (*Electric steel castings*)

Krauss-Maffei, A.G., München-Allach, Germany. (Castings)

Maximilianshütte, Eisenwerk-Gesellschaft m.b.H., Sulzbach-Rosenberg, Bavaria, Germany, Haidhof Works. (Ingots, billets, bars, small sections and thin plates)

Baltimore, Md.

Bethlehem Steel Co., Sparrows Point, Md., U.S.A. (Plates)

Barcelona

Funderia S.A. de, Manresa, Spain. (Castings)

Hierros y Aceros Industriales S.A., San Adrian de Besos, Barcelona, Spain. (Small castings)

Industrias del Besos, S.A., Barcelona, Spain. (Small sections and bars)

Industrias Mecanicas, Sociedad Anonima, Barcelona, Spain. (Castings)

Material y Construcciones S.A., Barcelona, Spain. (Castings)

Sucesora de Aceros Electricos S.A., Barcelona, Spain. (Castings)

Bergen

Stavanger Staal A.S., Jorpeland, near Stavanger, Norway. (Castings)

Berlin

Borsig A.G., Berlin-Tegel, Germany. (Ingots, forgings and castings)

VEB Magdeburger Armaturenwerke "Karl Marx", Magdeburg, Germany. (Castings)

VEB Maschinenfabrik und Eisengiesserei Dessau, Dessau, Germany. (Castings)

VEB Qualitats - und Edelstahl-Kombinat, Stahl - und Walzwerk Groditz, 8402 Groditz, Germany. (Forgings and castings)

VEB Schwermaschinenbau-Kombinat "Ernst Thalmann", Magdeburg-Buckau, Germany. (Ingots and forgings)

Bilbao

Acerias y Forjas de Azcoitia, Azcoitia Guipuzcoa, Spain. (Ingots and small rolled bars)

Aceros y Fundiciones del Norte Pedro Orbegozo y Cia. S.A., Hernani (Guipuzcoa), Spain. (Ingots, forgings and rolled bars)

Agrometal S.A., Miranda de Ebro Works, Bilbao, Spain. (Castings)

Amurrio, S.A., Talleres de, Amurrio, Alava, Spain. (Steel castings)

ARANZABAL S.A., Vitoria Alava, Spain. (Small castings)

Babcock & Wilcox, Sociedad Española de Construcciones.

Head Office: Calle Ercilla 1, Bilbao.

Works: Galindo-San Salvador del Valle. (Vizcaya) (Castings, ingots and forgings)

Compañia Auxiliar de Ferrocarriles, Beasain, Guipuzcoa, Spain. (Small castings and forgings)

Cooperativa Industrial Electrodos y Aceros, Boô, Santander, Spain. (Castings)

Crane-Fisa S.A., Bilbao, Spain. (Small castings)

Deusto, S.A. Talleres de, Luchana, Bilbao, Spain. (Ingots, castings and small forgings)

Echevarria, Sociedad Anonima, Bilbao, Spain. (Small sections and bars, small forgings and ingots)

Echeverria, Patricio, S.A., Legazpia, Spain. (Ingots, blooms, forgings and small bars)

Bilbao-continued

Eguiluz, Talleres, Miranda del Ebro, Burgos, Spain. (Castings)

Espanoles, Astilleros, S.A., Factoria de Reinosa, Spain. (Ingots, forgings, castings, plates and sections)

Factoria de Sestao. (Small castings, ingots and forgings)

Euskalduna, Compania, Fundicion de Asua, (Near Bilbao) Vizcaya, Spain. (Castings)

Ferretera Montanesa S.A., Torrelavega, Spain. (Castings)

Forjas Alavesas, S.A., Vitoria, Spain. (Ingots, rolled bars and forgings)

Fundiciones Arriaran S.A., Lazcano, Guipuzcoa, Spain. (Castings)

Fundiciones del Estanda S.A., Beasain, Spain. (Castings) Fundiciones Echevarria S.A., Beasain, Guipuzcoa, (Ingots, small rolled bars and castings)

Fundiciones Especiales Zaragoza S.A., Zaragoza, Spain. (Castings)

Guivisa S.A., Basauri, Bilbao, Spain (Castings)

Llodio, Aceros de, S.A., Llodio, near Bilbao, Spain. (Castings, ingots, forgings and rolled bars)

Luzuriaga, Victorio, S.A., Pasajes, Guipuzcoa, Spain. Works: Usurbil, Guipuzcoa. (Castings)

Nueva Montana Quijano S.A., Nueva Montana, Santander, Spain. (Castings)

Olarra S.A.

Works: Erandio, Bilbao, Spain. (Ingots and small bars)

Works: Larrondo. Lujúa. Viscaya. Spain. (Ingots and rolled bars)

Siderurgica Ebroacero S.A., Zaragoza, Spain. (Castings) Sifema S.A. Bilbao. (Steel castings)

Vizcaya, Sociedad Altos Hornos de, Bilbao, Spain.
(Ingots, bars, sections, forgings and plates up to 10 mm thick)

Bombay

Mukand Iron & Steel Works, Ltd., Kurla, Bombay 70, India. (Castings)

Bordeaux

Société Anonyme d'Exploitation des Aciéries de Bordeaux, Pessac, Gironde, France. (Castings)

Sud Ouest, Société des Forges et Aciéries du, Bordeaux (Gironde), France. (Castings and forgings)

Bremen

Bremer Vulkan, Schiffbau und Maschinenfabrik, Bremen-Vegesack, Germany. (Castings)

Klöckner-Werke A.G., Hutte Bremen, Germany. (Plates)

Brisbane

Bradford Kendall Ltd., Runcorn, Brisbane, Queensland. (Castings)

Walkers Ltd., Maryborough, Queensland, Australia. (Forgings and castings)

Buenos Aires

Aceria Bragado S.A.I.C., Bragado, Argentina. (Castings) Astilleros Rio Santiago, Ensenada, Buenos Aires, Argentina. (Steel castings)

Herchamet S.A.I.C., Fundicion Electrica de Aceros, Velez Sarfield, Rosario, Argentina. (Castings)

Marathon Argentina, Aceros Finos y Especiales S.A., Villa Constiticion, Santa Fe, Argentina. (Ingots, forgings and forged bars)

Calcutta

Bhartia Electric Steel Co., Ltd., Calcutta, India. (Castings)

Burn & Co., Ltd., Howrah, India. (Castings)

Electrosteel Castings Ltd., Khardah, West Bengal, India. (Castings)

Hindustan Steel Ltd.,

Rourkela, Orissa, India. (Ingots, slabs and plates)
Durgapur Steel Plant, West Bengal, India. (Blooms, billets, bars and sections)

Bhilai Steel Project, Bhilai, Madhya Pradesh, India. (Ingots, blooms, billets and sections)

Indian Iron & Steel Co., Ltd.,

Burnpur Works, Burnpur, West Bengal, India. (Sections and angles)

Kulti Iron Works, Kulti, India. (Castings)

Indian Tube Company, Ltd., Jamshedpur, India. (Seamless tubes)

Kumardhubi Engineering Works Ltd., P.O. Box Kumardhubi Dist. Dhanbad (Bihar), India. (Castings)

Metal & Steel Factory, Ishapore, West Bengal, India. (Ingots, blooms, billets, forgings, castings and bars)

National Iron & Steel Co., Ltd., Stephen House, Calcutta, 1, India. (Castings)

Tata Engineering & Locomotive Co., Ltd., Jamshedpur 4, India. (Castings)

Tata Iron & Steel Co., Ltd., Jamshedpur, India. (Blooms, billets, bars, plates and sections)

Chicago

Bethlehem Steel Co., Burns Harbour Plant, Chesterton, Indiana, U.S.A. (Rolling mill for plates)

Colorado Fuel & Iron Corporation, Minnequa Works, Pueblo, Colorado, U.S.A., (Ingots, bars and small sections)

Falk Corporation, Milwaukee, Wis., U.S.A. (Castings)
Finkl, A., & Sons Company, Chicago, Illinois, U.S.A. (Forgings)

Granite City Steel Co., Granite City, Illinois, U.S.A.

Inland Steel Co., Indiana Harbour, Indiana, U.S.A. (Ingots, blooms, billets and slabs)

Republic Steel Corporation, Chicago Plant, Chicago, Illinois, U.S.A.

Works: 118th Street, Chicago Rolling Mills, East Chicago, Ind., (Angles and bars)

Chicago—continued

U.S. Steel Co., Pittsburgh, Pa., U.S.A.

Gary Works, Gary Ind. (Billets, blooms, plates, sections, bars and forgings)

South Works, South Chicago, Illinois, (Plates, sections and bars)

Cleveland, O.

American Rolling Mill Co., Middletown, O., U.S.A. (Castings and forgings)

Bethlehem Steel Corp.

Johnstown Plant, Johnstown, Pa., U.S.A. (Ingots, billets, slabs, plates and bars)

Lackawanna, N.Y., U.S.A. (Ingots, blooms, billets, bars, plates and sections)

Crucible Steel Corporation, Midland Division, P.O. Box 226, Midland, Pa. 1505g., U.S.A. (Ingots, slabs, billets, hot rolled and cold drawn bars)

Edgewater Corporation, Oakmont, Pennsylvania, U.S.A. (Ingots and forgings)

Great Lakes Steel Corporation, Division of National Steel Corporation, Ecorse, Detroit 29, Michigan, U.S.A. (Ingots, billets, bars, slabs, plate, blooms, sheet and coiled strip)

Jones & Laughlin Steel Corporation, Pittsburgh, Pa., U.S.A.

Latrobe Forge & Spring, Inc., Latrobe, Pa. (Ingots and forgings)

National Forge Co.

Erie Division, Erie, Pennsylvania, U.S.A. (Ingots, forgings and castings)

Irvine, Warren County, Pennsylvania, U.S.A. (Ingots and forgings)

Ohio Steel Foundry Co., Lima, Ohio, U.S.A. (Ingots, forgings and castings)

Pittsburgh Steel Company, Pittsburgh 30, Pa., U.S.A.

Works: Monessen, Pa. (Ingots, billets and slabs)

Works: Allenport, Pa. (Rolling mills)

Republic Steel Corporation, Cleveland, O., U.S.A.

Buffalo Plant, Buffalo, N.Y., U.S.A.

Central Alloy District, Massillon Plant, Massillon, O., U.S.A.

Cleveland District, Cleveland, O., U.S.A.

Corrigan McKinney Plant. (Ingots, blooms and billets)

Upson Nut Plant. (Round and square bars) Youngstown District, Youngstown, O., U.S.A.

Sharon Steel Corporation, Roemer Works, Farrell, Pa., U.S.A., (Ingots, blooms, billets, narrow plates and sections)

United States Steel Corporation, Pittsburgh, Pa., U.S.A. Clairton Works, Clairton, Pa. (Ingots, blooms, bars and sections)

Duquesne Works, Duquesne, Pa. (Ingots, billets, blooms and bars)

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Cleveland O .- continued

United States Steel Corporation—continued

Homestead District Works, Pa., (including McKees Rock Works.) (Ingots, billets, blooms, slabs, plates, sections and forgings)

Irvin Works, Dravosburg, Pa. (Rolling mills for

thin plates)

McDonald Mills, Youngstown. (Rolling mills for bars and sections)

Ohio Works, Youngstown. (Ingots, billets and blooms)

Youngstown Sheet and Tube Company, Brier Hill Works, Youngstown, Ohio, U.S.A.

Campbell Works, Campbell, Mahoning Co., Ohio. (Ingots and plates up to 12,5 mm in thickness)

Cologne (Köln)

Boschgotthardshütte, Otto Breyer G.m.b.H., Edelstahlwerk-Press. u. Hammerwerk-Mechanische Werkstätten, Hüttental-Weidenau, Germany. (Ingots and forgings)

Breitenbach, Ed., G.m.b.H., Hüttental-Weidenau/Sieg, Germany. (Castings)

Edelstahlwerke Buderus A.G., Wetzlar, Germany. (Ingots, blooms, billets, bars, forgings and plates)

Eschweiler Bergwerks-Verein Hüttenbetriebe, Eschweiler-Aue, Germany. (Ingots and seamless tubes)

Gussstahlwerke Risch K.G., Bergisch-Gladbach, Germany. (Electric steel castings)

Klockner-Werke A.G., Mannstaedt-Werke, Troisdorf, Germany. (Rolling mills for sections)

Schmidt & Clemens, Edelstahlwerk, Kaiserau b/Engelskirchen Bez. Köln, Germany. (Ingots, forgings, castings and bars)

Stahlwerke Südwestfalen, A.G., Werk Geisweid, Geisweid, Kries Siegen, Germany. (Ingots, bars, billets, thin plates, sheets and coils)

Werksgruppe, Geisweid, Works Niederschelden, Germany. (Ingots and slabs)

Copenhagen

Burmeister & Wain's Maskin-og Skibsbyggeri, Aktieselskabet, Copenhagen, Denmark. (Ingots, forgings and castings)

Danske, (Det), Staalvalsevaerk A/S., Frederiksvaerk, Denmark. (Plates, sections and bars)

Helsingors Skibsvaerft-og Maskinbyggeri A/S., Aktieselskabet, Elsinore, Denmark. (Forgings and castings)

Dortmund

Bischoff-Werke K.G., AB Stahlgiesserei Ludinghausen/ Westphalia, Germany. (Castings)

Edelstahlwerk Witten A.G., Witten-Ruhr, Germany. (Ingots, billets, bars, forgings and narrow flats)

Eisenwerk Bohmer, Witten, Ruhr, Dortmund, Germany. (Castings)

Eisenwerk Geweke, R. & C. R. Lange K.G., Hagen-Haspe, Germany. (Electric steel castings)

Dortmund—continued

Eisenwerk Rödinghausen K.G., Lendringsen Krs. Iserlohn, Germany. (Castings)

Gottwald, Leo Werk Hattingen, Ruhr, Germany. (Small forgings)

Gussstahlwerk Carl Bönnhoff, Wetter/Ruhr, Germany. (Ingots and castings)

Gussstahlwerk Wittman A.G., Hagen-Haspe, Germany. (Castings)

Hoesch Hüttenwerke, A.G., Dortmund, Germany.

Werk Phoenix Hörde, Dortmund-Hörde. (Ingots, plates and castings)

Werk Union, Dortmund. (Bars and sections) Werk Westfalenhütte, Dortmund. (Ingots, billets, plates, bars and sections)

Klöckner-Werke A.G., Hütte-Haspe, Hagen Haspe, Germany. (Rolling mills for bars)

Knorr-Bremse G.m.b.H., Volmarstein-Schmandbruch, Germany. (Castings)

Kruiner Gussstahlwerk, Gevelsberg, Germany. (Castinas)

Paderwerk Gebr. Benteler, Schlossneubaus, Germany. (Seamless tubes)

Rheinstahl Hüttenwerke A.G., Henrichshütte, Hattingen, Ruhr, Germany. (Ingots, plates, forgings and castings)

Schutte, Meyer & Co., G.m.b.H., Letmathe, Westphalia, Germany. (Small castings)

Stahlwerke Südwestfalen A.G., Werksgruppe Hagen, Werk Wehringhausen, Hagen, Germany. (Ingots, bars and forgings)

Wittener Hutte Aktiengesellschaft, Witten, Ruhr, Germany. (Castings)

Dunkerque

Creusot Loire, Usine des Dunes, Malo les Bains (Nord), France. (Ingots, billets, blooms, bars and forgings)

Generale d'Hydraulique et de Mecanique, Usine Metallurgiques de Marquise Rinxent, Pas de Calais. (Castings)

Paris et d'Outreau, Acieries de, Société Anonyme, Usines d'Outreau Pas de Calais. (Castings)

Union Siderurgique du Nord et de l'Est de la France, 'USINOR", Usine de Dunkerque, Dunkerque (Nord), France. (Ingots and plates)

Durban

Mangolds Engineering, Port Elizabeth, South Africa. (Small castings)

Dusseldorf

August Thyssen-Hütte A.G., Duisburg-Hamborn, Germany.

Area Hamborn. Steelworks Beeckerwerth, Bruckhausen and Ruhrort., (Ingots, billets, slabs, plates and sections)

Area Mülheim. Steelworks Mülheim. (Ingots, slabs and plates)

Duisburg Huttenheim. (Plates)

Bergische Stahlindustrie K.G., Remscheid, Germany. (Castings)

Dusseldorf-continued

Deutsche Edelstahlwerke A.G., Krefeld, Germany.

(Ingots, forgings and rolled materials)

Fried. Krupp Hüttenwerke A.G., Bochum, Germany. Works: Bochum. (Ingots, plates, forgings, castings

Works: Rheinhausen. (Ingots, bars and sections) Grossmann, C., Eisen-und Stahlwerk A.G., Solingen-Wald, Germany. (Castings)

Gutehoffnungshütte Sterkrade A.G., Werk Sterkrade, Oberhausen-Sterkrade, Germany. (Forgings)

Hüttenwerk Oberhausen, A.G., Oberhausen, Germany. (Ingots, plates, sections and bars)

Mannesmann A.G. Hüttenwerke, Duisburg-Huckingen, Germany. (Ingots, slabs and bars)

Mannesmannrohren-Werke G.m.b.H., Dusseldorf. Ger-

many. (Seamless and welded tubes)
Meyer, F. Stahl, -Draht & Röhrenwerke, Dinslaken,
Germany. (Ingots, billets for tubes and bars)

Niederrheinische Hutte A.G., Duisburg, Germany. (Rolling mill for narrow flats and sections)

Rheinstahl Giesserei A.G., Gussstahlwerke Gelsenkirchen,

Germany. (Castings) Rheinstahl Giesserei A.G., Gussstahlwerke Oberkassel, Dusseldorf-Oberkassel, Germany. (Ingots and castings)

Rheinstahl Hüttenwerke A.G., Werk Friedrich Wilhelms-Hütte, Mülheim und Meiderich, Germany. (Castings)

Stahl- u. Röhrenwerke Reisholz G.m.b.H., Works at Reisholz. (Ingots and seamless tubes)

Stahlwerke Bochum A.G., Bochum, Germany. (Castings, rolled materials and plates)

El Ferrol

Astilleros y Talleres del Noroeste S.A., El Ferrol del Caudillo, Spain. (Small forgings and small castings) Empresa Nacional Bazan, El Ferrol del Caudillo, Spain. (Castings)

Emden

Sande, Giesserei, Sande-Oldenburg, Germany. (Castings)

Australian Iron & Steel Pty. Ltd., Steelworks, Kwinana, W. Australia. (Small bars and sections)

Bradford Kendall Ltd., South Beach, South Fremantle, Australia. (Castings)

Vickers Hadwa Pty. Ltd., Perth. W. Australia. (Castings)

Combinatul Siderurgic Gheorghiu Dej, Galatz, Rumania. (Plates)

Galveston

Cameron Iron Works Inc., Houston, Texas. (Ingots and forgings).

Gdansk

Zaklady Mechaniczne Im. Gen. K., Swierczewskiego, Elblag, Poland. (Castings)

Zaklady Metalurgiczne Poznan, "Pomet", Poznan ul Krancowa 15, Poland. (Castings)

Genoa

A.S.S.A. Acciaierie di Susa Società Anonima, Turin, Italy. Head Office: Turin. Works: Susa. (Castings) Cantieri Navali del Tirreno e Riuniti, S.p.A., Riva

Trigoso, Genoa, Italy. (Small forgings)

FIAT, Società per Azioni, Sezione Ferriere Piemontesi. Turin, Italy. (Ingots, plates, sections; also seamless and welded tubes)

Fit Ferrotubi-Fabbrica Italiana Tubi Ferrotubi, Italy. (Ingots, billets and weldless rolled and drawn tubes)

Fonderia Acciaieria Giovanni Mandelli, Turin, Italy,

"ITALSIDER" S.D.A. Head Office: Via Corsica 4, Genoa, Italy.

S.I.A.C., Genoa. (Ingots, forgings, plates and castings) Oscar Sinigaglia Works, Genoa-Cornigliano, (Ingots, slabs and plates)

Nazionale "Cogne", S.p.A. Head Office: Turin, Italy. Works: Aosta. (Ingots, blooms, billets and bars)

Duro-Felguera, Sociedad Metalúrgica, La Felguera, Asturias, Spain. (Castings)

Empresa Nacional Siderurgica, S.A. (ENSIDESA). Avilés, Spain. (Ingots, slabs and billets for re-rolling, plates and sections)

Talleres de Moreda S.A., Gijon. (Forgings)

Trubia, Fábrica Nacional de, Trubia Asturias, Spain. (Castings and forgings)

Union de Siderurgicas, Asturianas, S.A. (UNINSA)

Fabrica de Mieres, Asturias, Spain. (Sections, bars and plates up to 15 mm in thickness)

Fabrica de Gijon, Gijon, Spain. (Rivet bars and castings)

Factoria de La Felguera, La Felguera, Asturias, Spain. (Ingots, billets, plates and sections)

Gothenburg

Björneborgs Jernverks Aktiebolag, Björneborg, Sweden. (Ingots and forgings)

Bofors Aktiebolaget, Bofors, Sweden. (Ingots, forgings, castings and rolled bars)

Klafreströms Bruk, A/B, Klavreström, Sweden. (Small

Motala Verkstad, A/B, Motala Verkstad, Sweden. (Ingots and castings)

Stridsberg & Biorck, A.B., Trollhattan, Sweden. (Castings)

Svenska Kullagerfabriken A/B, Hellefors Jernverk, Hällefors, Sweden. (Ingots and bars)

Uddeholms Aktiebolag, Uddeholm, Sweden.

Works at Degerfors. (Ingots, plates, sections and bars) Works at Hagfors. (Castings, ingots, forgings, bars and sections)

Works at Nykroppa. (Ingots)

Works at Storfors. (Seamless tubes)

LLOYD'S REGISTER OF SHIPPING

Halifax, N.S.

Hawker Siddeley Canada Ltd., Trenton Works, Trenton, N.S. (Forgings)

Maritime Steel and Foundries, Ltd., New Glasgow, N.S. (Small castings)

Sydney Steel Corporation, Sydney, N.S., (Ingots, billets and sections)

Hamburg

Ellerbrock, Hans, Stahlgiesserei und Maschinenfabrik, Hamburg, Germany. (Castings)

Hannover

Eisen-und Stahlwerk Pleissner G.m.b.H., Herzberg/ Harz, Germany. (Castings)

Friedrich-Carl-Hütte G.m.b.H., Delligsen über Alfeld/ Leine, Germany. (Castings)

Klockner Werke A.G.

Works: Huttenwerke, Georgsmarienhutte, Germany.
(Ingots and bars)

Works: Osnabruck, Germany. (Forgings and castings)

Salzgitter Hüttenwerk A.G., Salzgitter-Drütte, Germany. (Ingots, plates, bars and sections)

Sollinger Hütte G.m.b.H., Uslar/Solling, Germany. (Castings)

Stahlwerke Peine-Salzgitter A.G., Werke Peine, Peine, Germany. (Ingots, billets, sections and bars)

Stahlwerke Peine-Salzgitter A.G., Werk Salzgitter, Salzgitter-Drutte, Germany. (Ingots, plates, bars and sections)

Tweer, Reinhard, G.m.b.H., Sennestadt/Westf., Germany, Works: Sennestadt. (Castings)

Haren-Groningen

Stork-Volma N.V. Gorredijk, Holland. (Small castings)

Helsingborg

Hoganas A/B, Hoganas, Sweden. (Castings)

Helsinki/Helsingfors

Ahlstrom, A., Oy, Osakeyhtio Karhulan Tehtaat, Karhula Bruk, Karhula, Finland. (Castings)

Stenburg, John, OY-AB, Helsingfors, Finland. (Small castings)

Vuoksenniska AB, Oy, Imatra Steel Works, Imatra, Finland. (Ingots, slabs, blooms and billets, bars, sections and castings)

Hiroshima

Kotobuki Industries Co., Ltd., Hiro Works, Kure, Japan. (Castings)

Hong Kong

Cheoy Lee Shipyard, Lantau Island, Hong Kong. (Castings)

Shun Fung Ironworks Ltd., Kowloon, Hong Kong. (Castings)

Istanbul

Eregli Demir ve Celik Fabrikalari T.A.S., Eregli, Turkev. (Ingots and plates)

Makine ve Kimya Endustri, Cetik Fabrikasi, Kirikkale, Turkey. (Ingots, forgings, rolled sections and bars) Turkiye Demir ve Celik Isletmeleri, Karabuk, Turkey.

(Ingots, thin plates, rolled sections and bars)

Jamshedpur

Heavy Engineering Corp. Ltd., Foundry Forge Plant, P. O. Dhurwa, Ranchi, India. (Castings)

Katowice

Huta 1-Maja, Gliwice, Poland. (Ingots and forgings)
Huta Baildon, Katowice, Poland. (Ingots, forgings and bars)

Huta Batory, Chorzow-Batory, Poland. (Forgings, plates and tubes)

Huta Bierut, Czestochowa, Poland. (Seamless tubes)
Huta Bobreck, Bytom, Poland. (Ingots, slabs and blooms)

Huta im M. Buczka, Sosnowiec, Poland. (Seamless tubes)

Huta Dzierzynski, Dabrowa Gornicza, Poland. (Billets, sections and bars)

Huta Florian, Swietochlowice, Poland. (Angles and bars)
Huta Jednosc, Siemianowice Slaskie, Poland. (Ingots
and seamless tubes)

Huta Kosciuszko, Chorzow, Poland. (Billets, blooms, sections and rivet bars)

Huta Labedy, Labedy, Poland. (Flats and sections)
Huta im. Lenina, Krakow, Poland. (Ingots, slabs, plates up to 12 mm)

Huta Malapanew, Ozimek k/Opola, Poland. (Castings) Huta Nowotko, Ostrowiec Swietokrzyski, Poland.

(Sections)

Huta Pokoj, Ruda Slaska, Poland. (Plates, sections and small forgings)

Huta Stalowa Wola, Stalowa Wola, Poland. (Castings, forgings, plates and sections)

Huta Warszawa, Warsaw, Poland. (Ingots, forgings and rolled bars)

Huta Zawiercie, Zawiercie, Poland. (Flats and bars)

Zaklady Urzadzen Chemicznych i Armatury Przemyslowej Kielce, Poland. (Castings)

Zaklady Urzadzen Technicznych "Zgoda", Swietochlowice, Poland. (Forgings)

Kiel

Nordische Stahlwerke, Bach & Co., Neumünster Germany. (Castings)

Kobe

Aichi Steel Works Ltd.

Chita Plant, Aichi Prefecture, Japan. (Ingots and bars)
Kariya Plant, Aichi Prefecture, Japan. (Ingots and

bars)

Kobe-continued

Asano Tekkosho Co., Ltd., Saijo-Shi, Shikoku, Japan. (Small forgings)

Chubu Steel Plate Co., Ltd., Nakagawa Works, Nagoya, Japan. (Ingots and plates)

Daido Steel Co., Ltd.

Chita Plant, Nagoya, Aichi Prefecture, Japan. (Ingots, billets and bars)

Hoshizaki Plant, Nagoya, Japan. (Ingots and bars) Tsukiji Plant, Nagoya, Japan. (Ingots, forgings and castings)

Daitetsu Steel Industrial Co., Ltd., Osaka, Japan. (Ingots and sections)

Endo Iron Works Co., Ltd., Osaka, Japan. (Forgings) Go Iron Works, Ltd., Tarui Works, Tarui, Japan. (Small castings)

Hitachi Metals, Ltd., Yasugi Works, Yasugi, Japan. (Ingots, bars and forgings)

Hitachi Shipbuilding & Engineering Co., Ltd.

Chikko Shipyard, Osaka, Japan. (Ingots eastings, and forgings)

Innoshima Shipyard, Innoshima, Japan. (Forgings and small castings)

Howa Machinery, Ltd., Inazawa Plant, Aichi Prefecture, Japan. (Castings)

Ishikawajima-Harima Heavy Industries Co., Ltd., Aioi Works, Aioi, Japan. (Castings and forgings)

Izuo Chukosho Co., Ltd., Osaka, Japan. (Castings)

Japan Drop Forge Co., Ltd., Amagasaki, Japan. (Small forgings)

Japan Iron-Sand Steel Co. Ltd., Shikama Works, Himeji, Japan. (Ingots, bars and sections)

Kansai Steel Corp., Sakai, Japan. (Ingots, bars and flat bars)

Kansai Tekko Co., Ltd., Amagasaki, Japan. (Small forgings)

Kawasaki Heavy Industries Ltd.

Hyogo Cast Steel Works, Kobe, Japan. (Castings) Kobe Works, Kobe, Japan. (Castings)

Kawasaki Steel Corporation.

Chita Works, Handa City, Japan. (Ingots and castings)

Fukiai Works, Kobe, Japan. (Blooms and sections)
Mizushima Works, Mizushima, Japan. (Ingots,
forgings, castings, bars, plates and sections)

Kinka Kikai Co., Ltd., Gifu, Japan. (Castings)

K.K. Teikoku Kokan Seizosho, Osaka, Japan. (Seamless tubes)

Kobe Steel Ltd.

Works: Amagasaki, Japan. (Ingots, sections and bars)

Works: Kakogawa Plant, Kakogawa City, Hyogo Prefecture, Japan. (Ingots and plates)

Works: Kobe, Japan. (Ingots, blooms, billets, bars castings and seamless tubes)

Works: Takasago Plant, Takasago, Japan. (Ingots, forgings and castings) Kobe-continued

Kokko Steel Works, Ltd., Osaka, Japan. (Ingots, bars and castings)

Kokoku Steel Casting Co., Ltd., Osaka, Japan. (Castings) Komatsu Ltd.

Awazu Plant, Komatsu, Japan. (Castings) Osaka Plant, Hirakata, Osaka Prefecture, Japan. (Castings)

Kubota Ltd., Hirakata Plant, Hirakata, Osaka, Japan. (Castings)

Kureha Seiko Co., Ltd., No. 1, 5-Chome Takeshima-Cho, Nishiyodogawa-Ku, Osaka, Japan. (Castings)

Kurimoto Iron Works Ltd., Kagaya Factory, Osaka, Japan. (Castings)

Maekawa Electric Steel Castings Co., Osaka, Japan. (Castings)

Maizuru Jukogyo Ltd., Maizuru, Japan. (Small castings)

Mitsubishi Heavy Industries Ltd.

Kobe Shipyard & Engine Works, Kobe, Japan. (Ingots, small forgings and castings)

Mihara Machinery Works, Mihara, Japan. (Castings and forgings)

Takasago Machinery Works, Takasago, Japan. (Forgings)

Mitsui Shipbuilding & Engineering Co., Ltd., Japan,

Fujinagata Works, Osaka, Japan. (Forgings)

Tamano Works, Tamano, Japan. (Ingots, forgings and castings)

Mitsumoto Valve Manufacturing Co., Ltd., Domyoji, Osaka, Japan. (Small forgings and small castings)

Miyazaki Iron Works, Co., Ltd., Osaka, Japan. (Small forgings)

Nakayama Steel Works, Ltd., Osaka, Japan. (Ingots and plates)

Nippon Kokan Kabushiki Kaisha, Fukuyama Iron Works, Fukuyama, Japan. (Ingots, blooms, sections and plates)

Nippon Sharyo Seizo Kaisha Ltd., Nagoya, Japan. (Castings)

Nippon Steel Corporation.

Hirohata Works, Himeji City, Japan. (Ingots, billets, plates and sections)

Nagoya Works, Nagoya, Japan. (Ingots, plates and electric resistance welded tubes)

Sakai Works, Sakai, Osaka, Japan. (Ingots, sections and thin plates)

Nippon Steel Foundry Co., Ltd., Osaka, Japan. (Castings)

Okamoto Iron Works Co., Kobe, Japan. (Forgings)

Onomichi Anchor Manufacturing Co., Ltd., Onomichi, Japan. (Castings)

Osaka Chain & Machinery Manufacturing Co., Ltd., Kaizuka Works, Osaka, Japan. (Small castings)

Osaka Steel Casting Co., Ltd., Osaka, Japan. (Small castings.)

Kobe-continued

Rikimi Cast Steel Co. Ltd., Osaka, Japan. (Small castings)

Sanyo Special Steel Co. Ltd., Himeji, Japan. (Ingots, forgings and rolled bars)

Seo Koatsu Kogyo Co., Ltd., Osaka, Japan. (Small forgings)

Sumitomo Electric Industries, Ltd., Itami Works, Itami, Hyogo Prefecture, Japan. (Ingots and small bars)

Sumitomo Metal Industries, Ltd.

Osaka Steel Works, Osaka, Japan. (Castings, forgings and bars)

Steel Tube Works, Amagasaki, Japan. (Ingots, forgings, small bars, sections and seamless tubes)
 Wakayama Steel Works, Wakayama, Japan. (Ingots, plates, seamless tubes and electric resistance

welded tubes)

Sumitomo Shipbuilding & Machinery Co., Ltd. Niihama Works, Niihama, Japan. (Castings)

Tamashima Works, Tamashima, Japan. (Castings)

Takada Steel Works, Ltd., Takada City, Nara Prefecture, Japan. (Castings)

Teikoku Steel Casting Co., Ltd., Osaka, Japan. (Castings) Tokai Special Steel Co., Ltd., Nagoya, Japan. (Ingots) Topy Industries Ltd., Toyohashi Works, Toyohashi,

Japan. (Ingots, sections and flat bars)

Toshin Steel Co., Ltd., Himeji Works, Himeji, Japan. (Rolled sections and bars)

Toyo Kikai-Kinzoku Co., Ltd., Tsuchiyama Plant, Akashi, Japan. (Small castings and small forgings)

Wasino Machine Co., Ltd. Imamura Plant, Aichi Prefecture, Japan. (Castings) Komaki Plant, Aichi Prefecture, Japan. (Small

Yamato Kogyo Co., Ltd., Himeji, Japan. (Castings) Yamato Steel Works, Ltd., Osaka, Japan. (Ingots, sections and plates)

Yonago Steel Works, Ltd., Yonago, Japan. (Castings)

La Spezia

Faggian, Acciaierie Elettriche Pio, Soc. per Azioni, La Spezia, Italy. (Small castings)

Leghorn

"ITALSIDER" Alti Forni e Acciaierie Ruinite Ilva e Cornigliano S.p.A., Stabilimento di Portovecchio di Piombino, Italy. (Ingots, blooms, sections and bars)

Lisbon

"COMETNA" Companhia Metalurgica Nacional, S.A.R.L., Amadora, Portugal. (Castings)

Fundicoes do Rossio de Abrantes S.A.R.L., Rossio de Abrantes, Portugal. (Castings)

Metalurgica Duarte Ferreira S.a.r.l., Tramagal, Portugal. (Castings)

Siderurgia Nacional, S.a.r.l., Seixal, Portugal. (Sections and bars)

União Fabril, Companhia, Barreiro, Portugal. (Castings)

Los Angeles

Bethlehem Steel Co., Los Angeles 54, Cal., U.S.A. (Round bars)

Kaiser Steel Corporation, Fontana, Cal., U.S.A. (Ingots and plates)

Los Angeles Steel Casting Co., Los Angeles, Cal., U.S.A. (Castings)

United States Steel Corporation.

Torrance Works, Torrance, Calif., U.S.A. (Round bars and sections)

Geneva Works, Provo, Utah, U.S.A. (Plates)

Lyons

Creusot, Société des Forges et Ateliers du (S.F.A.C.) Usines Schneider, Le Creusot, France. (Ingots, forgings, castings, plates and sections)

Creusot Loire, Division Siderurgie, Usine du Marais, 42 Saint-Etienne, France. (Plates)

Usines d'Imphy-58, France. (Ingots, forgings, bars and sections)

Temple, Aciéries du, Saint-Michel de Maurienne, (Savoie) France. (Rolled and forged bars and billets)

Malmö

Kockums Jernverk, Kallinge, Sweden. (Ingots and castings)

Svedala-Arbra Aktiebolag, Svedala, Sweden. (Castings)

Mannheim

Dingler, Karcher & Cie., G.m.b.H., Saarländisches Stahlwerk, Worms/Rhein. (Castings)

Stahlwerk Mannheim A.G., Mannheim-Rheinau. (Castings)

Marseilles

Creusot-Loire, Usine de Pamiers, Pamiers, France. (Castings and forgings)

Feurs, Fonderies & Acieries Electriques de, Feurs (Loire), France. (Small castings)

Fonderies Meridionales, Marseilles, France. (Castings)

Marrel Frères, Société Anonyme des Etablissements, Usine des Etaings, near Rive-de-Ciers (Loire), France. (Ingots, plates and bars)

Pont A Mousson, Société des Fonderies de, Usine de Fumel, France. (Castings, centrifugal cast pipes)

Provence S.A., Fonderies et Aciéries de, Marseilles, France. (Castings)

Saut-du-Tarn, Société Nouvelle du, 81-Saint-Juéry, France. (Castings)

Tamaris, Société des Ateliers et Fonderies des, Tamaris (Gard), France. (Castings)

Ugine Kuhlmann, Savoie, France. (Ingots, billets, bars, sections, castings and forgings)

Melbourne

Davies & Baird Pty., Ltd., Newlands Road, Coburg, Melbourne, Australia. (Castings)

Steel Company of Australia, Pty., Ltd., Coburg, Melbourne. (Castings)

Vickers, Ruwolt, Pty., Ltd., Richmond, Melbourne. (Steel castings and ingots)

Metz (Saarbrücken District)

Pompey, Société des Aciéries de, Usine de Pompey, Meurthe et Moselle, France. (Ingots, blooms, billets, plates, angles and round bars)

Société des Aciers Fins de l'Est, F-57 Hagondange, France. (Ingots, blooms, billets, bars, plates and sheets)

Société Lorraine de Laminage Continu, Sollac, B.P.11, Florange, Moselle, France. (Ingots, slabs and plates)

Union Sidérurgique Lorraine, SIDELOR, Usine d'Homécourt, Meurthe et Moselle, France. (Ingots, blooms, billets, narrow plates and universal flats)

Usine de Rombas, Moselle, France. (Ingots, blooms, billets, bars and sections)

Union Siderurgique du Nord et de l'Est de la France, "USINOR".

GROUPE C

Usine de Longwy (Meurthe et Moselle), France. Section Mont Saint Martin. (Sections and plates) Section Senelle. (Ingots, blooms, bars and sections)

Usine de Thionville, Thionville (Moselle), France. (Forgings and castings)

Wendel-Sidelor.

Usine de Fenderie-Platinerie. 57 Hayange, France. (Plates)

Usine Hagondange, F-57 Hagondange, France. (Blooms, billets, bars and sections)

Usine de Micheville, Villerupt, Meurthe et Moselle, France. (Ingots, blooms, billets, bars and sections)

Usine Orne-Amont, F-54 Homecourt, France. (Ingots, blooms, billets, narrow plates and universal flats)

Usine de Rombas, F-57 Rombas, France. (Ingots, blooms, billets, bars and sections)

Mexico City

Altos Hornos de Mexico S.A., (A.H.M.S.A.), Monelova, Coah., Mexico. (*Plates*)

Milan

Amsco Italiana S.p.A., Milan. (Small castings)

Breda Fucine, S.p.A., Sesto San Giovanni, Milan. (Castings and forgings)

Breda Siderurgica, S.p.A., Sesto San Giovanni, Milan. (Ingots and sections)

Brescia, Acciaieria e Turbificio di, S.p.A., Brescia. (Ingots, sections, bars and castings)

Calcotto, Acciaieria e Ferriera del, S.p.A., Lecco. (Ingots, castings, bars, small sections and small forgings)

Milan-continued

Carlo Tassara, Stabilimenti Electtrosiderurgici S.p.A., Breno, Brescia, Italy. (Ingots and small forgings)

Ceretti, Pietro Maria, S.p.A., Ferriera dell' Ossola-Villadossola. (Castings)

Dalmine, S.p.A. Head Office: Milan.

Dalmine Costa Volpino, Bergamo. (Seamless tubes)
Dalmine Works, Bergamo. (Ingots and seamless tubes)

Falck, Acciaierie e Ferriere Lombarde. Head Office & Works: Milan. (Weldless rolled or drawn tubes)

Concordia Works, Sesto San Giovanni, Milan. (Ingots and plates)

Unione Works, Sesto San Giovanni, Milan. (Ingots, sections, bars, forgings and castings)

FOMAS—Forgiatura Moderna Acciai Speciali S.p.A., Osnago, (Como), Italy. (Forgings)

"ITALSIDER" Alti Forni e Acciaierie Riunite Ilva e Cornigliano S.p.A., Stabilimento di Lovere. (Sections, bars, castings and forgings)

Luigi Giudici, Società per Azioni, Rescaldina, Milan. (Small castings)

Metallurgica Marcora, S.n.C., Busto Arsizio (Varese).
(Weldless rolled and drawn tubes)

S.I.S.M.A.—Società Industrie Siderurgiche Meccaniche & Affini, Villadossola (Novara). (Rolled bars and rivets)

Stramezzi, P., & C., Acciaieria e Ferriera di Crema, Crema. (Ingots, bars, small sections and rivets)

Tosi, Franco, S.p.A., Legnano. (Forgings and castings) Villa, Giovanni, S.p.A., Officine Meccaniche-Fucinati-Stampati, Milan. (Forgings)

Mobile, Ala.

Kilby Steel Co., Furnace Division, Anniston, Ala., U.S.A. (Ingots)

Republic Steel Corporation, Alabama City, Ala., U.S.A. Tennessee Coal & Iron Division, United States Steel Corporation, Birmingham, Ala., U.S.A. Works: Ensley, Ala.; Rolling mills and forgings: Bessemer and Fairfield, Ala.

Montreal

Canadian Steel Foundries Division Hawker Siddeley Canada, Ltd., Longue Pointe, Montreal, P.Q., Canada. (Castings)

Crucible Steel Company of Canada, Ltd., Sorel, P.Q., Canada. (Ingots and forgings)

Dominion Steel & Coal Corporation Ltd., Montreal Works, 5870, St. Patrick Street, Montreal, P.Q., Canada. (Angles, bars and rivets)

Lynn Macleod Metallurgy, Ltd., Thetford Mines, P.Q., Canada. (Castings)

Manitoba Rolling Mills Division of Dominion Bridge Co., Ltd., Selkirk, Manitoba, Canada. (Billets, bars and sections)

Sorel Steel Foundries, Ltd., Sorel, P.Q., Canada. (Castings)

Montreal—continued

Steel Company of Canada, Hamilton, Ontario, Canada. Works: Montreal. (Bars and angles, plates and billets)

Unitcast Division of Midland-Ross of Canada Limited, Sherbrooke, Quebec (Castings)

Nagasaki

Japan Casting and Forging Corporation, Tobata-ku, Kitakyshu City, Fukuoka Prefecture, Japan. (Forgings and Castings)

Mitsubishi Heavy Industries Ltd., Nagasaki Works, Nagasaki, Japan. (Castings)

Mitsubishi Steel Manufacturing Co., Ltd., Nagasaki Works, Nagasaki, Japan. (Ingots, blooms, plates, forgings and castings)

Nagasaki Metal Industries Association, Kaizu-Machi, Isahaya-shi, Nagasaki, Japan. (Small forgings)

Osaka Steel, Tube Co., Ltd., Sasebo Works, Sasebo, Japan. (Seamless tubes)

Sasebo Heavy Industries Co., Ltd., Sasebo, Japan. (Ingots, forgings and castings)

Nantes

Sambre et Meuse, Société Anonyme des Usines & Aciéries de, Usines de Saint Brieuc (Côtes-du-Nord.) (Small castings)

Naples

Fucine Meridionali, S.p.A., Bari, Italy. (Castings and forgings)

"ITALSIDER" Alti Forni e Acciaierie Riunite Ilva e Cornigliano S.p.A.

Stabilimento di Taranto. (Ingots, slabs and plates)
"ITALSIDER" S.p.A., Centro Siderurgico di Bagnoli,
Naples. (Ingots, sections and bars)

Meridionali, Acciaierie e Tubificio, S.p.A., Bari, Italy. (Castings and weldless rolled or drawn tubes)

"Terni" Società per l'Industria e l'Elettricha.

Works: Terni. (Ingots, forgings, castings and plates)

Walworth Aloyco International S.p.A., Stabilimento di Napoli, Naples. (Castings)

Newcastle, N.S.W.

Broken Hill Proprietary Co., Ltd., Iron and Steel Works, Newcastle, N.S.W. (Ingots, billets, plates, sections, strip and castings)

Commonwealth Steel Co., Ltd., Waratah, Newcastle, N.S.W. (Castings, forgings, ingots and bars)

Newport News, Va.

Newport News Shipbuilding & Dry Dock Co., Newport News, Va., U.S.A. (Castings and forgings)

Odense

Varde Staalvaerk, Varde, Denmark. (Ingots and castings)

Oslo

Christiania Spigerverk, Oslo. (Ingots and bars, also rivet bars)

Drammens Jernstoberi & Mek-Verksted, A/S, Drammen. (Small castings)

Norsk Jernverk, A/S, Mo-i-Rana. (Electric steel ingots, billets, sections and bars)

Raufoss Ammunisjonsfabrikker, Raufoss. (Castings)

Strömmen Staal A/S,

Works: Raufoss. (Castings) Strömmen. (Castings)

Paris

Acieries & Fonderies de l'est, France.

Usine de Colombier-Fontaine. (Small Castings) Usine de Sainte-Suzanne. (Small electric castings)

Aciéries du Furan, St. Etienne (Loire), France. (Electric steel castings)

Aubert et Duval, Anciens Ets., Aciéries des Ancizes (Puyde-Dôme). (Ingots, rolled bars and forgings)

d'Auxonne, Aciéries & Fonderies, Auxonne (Côte d'Or), France. (Small castings)

Creusot Loire.

Division Mecanique Entreprises, Usines de St. Chamond-42 (Loire), France. (Forgings)

Division Transformation, Usines de l'Ondaine, 42-Firminy (Loire), France. (Ingots, billets, blooms, bars, castings and forgings)

Etablissement des Constructions et Armes Navales de Guerigny, Guerigny, France. (Ingots, bars, forgings and castings)

Ferry-Captain, S.A.R.L., Usines du Bussy-Joinville, France. (Electric steel castings)

Gennevilliers, Aciéries de, Gennevilliers (Seine), France. (Castings)

Geugnon, Forges de, Geugnon (S. & L.), France. (Rolling mill for plates)

Paris-Seine, Fonderies et Aciéries, Usine de la Folie, Avenue de Bobigny, Noisy-le-Sec. (Seine), France. (Castings)

Société Nouvelle des Acieries de Pompey, France. (Ingots, blooms, billets, plates, angles and round bars)

Philadelphia, Pa.

Atlantic Steel Castings Co., The, Chester, Pa., U.S.A. (Castings)

Bethlehem Steel Corporation., Bethlehem, Pa., U.S.A. (Ingots, forgings, bars and sections)
Lebanon, Pa., U.S.A. (Rolling mills for bars and rivets)

Steelton, Pa., U.S.A. (Castings)

Birdsboro Corporation, Birdsboro, Pa., U.S.A. (Castings)
Deemer Steel Casting Co., New Castle, Delaware, U.S.A. (Castings)

Donegal Steel Foundry Company, 601, East Market Street, Marietta, Pa., U.S.A. (Castings) Philadelphia, Pa.-continued

Empire Steel Castings Inc., Reading Pa., U.S.A. (Castings)

Lebanon Steel Foundry, Lebanon, Pa., U.S.A. (Small castings)

Lukens Steel Company, Coatesville, Pa., U.S.A. (*Plates*) Midvale-Heppenstall Company, Nicetown, Philadelphia, Pa., U.S.A. (*Forgings*)

Penn Steel Castings Co., Chester, Pa., U.S.A. (Castings) Pennsylvania Forge, Division of Chemetron Corporation, Tacony, Philadelphia 35, Pa., U.S.A. (Forgings)

Pennsylvania Steel Foundry and Machine Company, Hamburg, Pa., U.S.A. (Castings)

Phoenix Steel Corporation.

Works: Claymont, Delaware, U.S.A. (Plates)
Works: Structural Division, Phoenixville, Pa.,
U.S.A. (Sections, bars and rotary forged seamless
tubes)

Quaker Alloy Casting Co., Myerstown, Pa., U.S.A. (Small castings)

Standard Steel Division of Baldwin-Lima-Hamilton Corp., Burnham Pa., U.S.A. (Forgings)

United States Steel Corporation, Fairless Works, Fairless Hills, Pa., U.S.A. (Thin plates, bars and sections)

Wood, Alan, Steel Company, Conshohocken, Pa., U.S.A. (Blooms, billets and plates)

Piraeus

Nicolacopoulos G., & Co., Athens, Greece, Steelworks at Eleusis. (Castings)

Viomichania Chalyvon Ltd., Athens Greece. (Castings)

Port Kembla

Australian Iron & Steel Pty., Ltd., Port Kembla, N.S.W. (Plates, bars, sections and forgings)

Rijeka

Tvornica Dizalica I Ljevaonica "Vulkan" Rijeka 11, Yugoslavia. (Castings)

Zelezarna Ravne, Ravne na Koroskem, Yugoslavia. (Castings, forgings, billets and bars)

Zeljezara Sisak, Sisak Predgradje, Yugoslavia. (Seamless tubes)

Rio de Janeiro

Brasileira de Usinas Metalurgicas, Companhia, Usina de Neves Sao Goncalo, Estado do Rio de Janeiro, Brazil. (Ingots, sections and bars)

Companhia Ferro e Aco de Vitoria, Vitoria, State of Espirito Santo, Brazil. (Rolling mill for bars and sections)

Companhia Siderurgica Nacional, Usina Presidente Vargas, Volta Redonda, Estado do Rio de Janeiro, Brazil. (*Plates and sections*)

Usinas Siderurgicas de Minas Gerais S.A., Belo Horizonte, Estado de Minas Gerais, Brazil.

Works: Ipatinga, Estado de Minas Gerais. (Ingots, slabs and plates)

Rotterdam

Bakker N.V., Machinefabriek-Staalgieterij, Ridderkerk, Holland. (Ingots and castings)

Rotterdamsche Droogdok Maatschappij, Rotterdam, Holland. (Ingots, forgings and small castings)

Rouen

Manoir-Pompey, Acieries du, 27 Pitres, France. (Castings)

Société Métallurgique de Normandie, Mondeville, France. (Ingots, blooms, billets and bars)

Saarbrücken-Saar

"ARBED," Aciéries Réunies de Burbach - Eich -Dudelange.

Division de Belval, Esch-sur-Allzette, Luxembourg. (Ingots, blooms, billets, bars, angle bars and sections)

Division de Differdange, Differdange, Luxembourg, (Sections and bars)

Division de Dommeldange, Dommeldange, Luxembourg. (Ingots, forgings and castings)

Division d'Esch, Esch-sur-Allzette, Luxembourg. (Ingots, bars and sections)

Division de Burbach, Sarrebruck. Hostenbach Works. (*Plates*)

A.G. der Dillinger Huttenwerke, Dillingen/Saar. (Ingots and plates)

Dingler, Karcher & Cie., G.m.b.H., Saarbrücken, Saar. (Castings)

Minière et Métallurgique de Rodange, Luxembourg. (Sections)

Neunkircher Eisenwerk A.G. Neunkirchen/Saar. Neunkirchen Works. (Ingots, bars and sections) Homburg Works. (Ingots and seamless tubes)

Pohlig-Heckel Bleichert, Vereinigte Maschinenfabriken A.G., Abt. Stahlformgiesserei, Werk Heckel, Rohrbach/Saar, Germany. (Castings)

Rohrenwerke Bous G.m.b.H., Bous/Saar. (Seamless tubes)

Stahlwerke Rochling-Burbach. G.m.b.H.

Works: Burbach. (Ingots, billets and sections)
Works: Völklingen. (Castings, ingots, billets, bars
and forgings)

Union Siderurgique du Nord et de l'Est de la France, "USINOR".

GROUPE C.

Usine de Longwy (Meurthe et Moselle), France. Section Mont Saint Martin. (Sections and plates)

Section Senelle. (Ingots, blooms, bars and sections)
Usine de Thionville, Thionville (Moselle), France.
(Forgings and castings)

Wendel-Sidélor, Usine de St. Jacques, F-57 Hayange, France. (Sections)

Wurth, Société Anonyme des Anciens Etablissements Paul, Luxembourg. (Castings)

San Francisco, Cal.

Enterprise Engine & Foundry Co., South City, Cal., U.S.A. (Castings)

General Metals Corporation, Oakland, Cal., U.S.A. (Castings)

Pacific States Steel Corporation, Union City, Cal., U.S.A. (Ingots, sections and bars)

Pacific Steel Castings Co., Berkeley, Cal., U.S.A. (Castings)

Santos

Companhia Siderurgica Paulista, Cosipa, Cubatao, Sao Paulo, Brazil. (Ingots and plates)

Sao Paulo

Acos Villares S.A., Sao Caetano do Sul, Sao Paulo, Brazil. (Castings, forgings, billets and bars)

Seattle, Wash.

Bethlehem Steel Co., Seattle, Wash., U.S.A. (Sections, bars and narrow flats)

Jorgensen, Earle M. Co., Forge Division, Seattle, Wash. Olympic Steel Works, Seattle, Wash., U.S.A. (Castings) Washington Iron Works, Seattle, Wash., U.S.A. (Castings)

Shimonoseki

Hitachi Ltd., Kasado Works, Kudamatsu, Japan. (Castings and forgings)

Hitachi Metals, Ltd., Tobata Works, Tobata, Japan. (Castings)

Japan Steel Works Ltd., Hiroshima Works, Hiroshima, Japan. (Forgings and castings)

Kure Shipbuilding & Engineering Co., Ltd., Kure, Japan. (Small forgings)

Maekawa Electric Steel Castings Co., Ltd., Tobata Factory, Kitakuyushu, Japan. (Castings)

Matsuya Kogyo Co., Ltd., Fukuoka, Japan. (Small forgings)

Mitsubishi Heavy Industries, Ltd., Hiroshima Works, Hiroshima, Japan. (Ingots, castings and small forgings)

Mitsui Miike Machinery Co., Ltd., Miike Works, Omutashi, Japan. (Castings)

Nippon Steel Corporation.

Engineering, Machinery and Foundry Division, Tobata, Kitakyushu, Japan. (Castings and forgings)

Tobata Area Works, Japan. (Ingots and plates)

Yawata Area Works, Japan. (Plates, sections, ingots and forgings)

Nisshin Steel Works, Ltd., Kure Works, Kure, Japan. (Ingots, blooms, billets and strip)

Okano Valve Manufacturing Co., Ltd., Moji. Works: Yukuhashi, Japan. (Small castings and small forgings) Ozuki Seikosho Ltd., Shimonoseki, Japan. (Castings)

Shimonoseki-continued

Sumitomo Metal Industries, Ltd., Kokura Steel Works, Kitakyushu-City, Japan. (Ingots, billets, bars and sections)

Ube Industries, Ltd., Ube Machinery Works, Ube, Japan. (Ingots, forgings and castings)

Wakamatsu Sharyo Co. Ltd., Kitakyushu-City, Japan. (Small castings)

Singapore

National Iron & Steel Mills Ltd., Jalan Besi Baja, Jurong Industrial Estate, Singapore. (Small sections and bars)

United Engineers (Singapore) Pte. Ltd., Kampong Bahru Foundry, Singapore. (Castings)

Split

Industrija Masina i Livnica, Tuzla, Yugoslavia. (Castings)

Rudarsko-Metalurski Kombinat-Zenica, Zeljezara Zenica, Zenica, Yugoslavia. (Billets, bars, sections and forgings)

Rudnici i Zelezara Smederevo, Smederevo, Yugoslavia.
(Small castings)

Rudnici I Zelezarnica, "Skopje", Skopje, Yugoslavia. (Plates)

Titovi Zavodi Litostroj, Ljubljana, Yugoslavia. (Castings)

Združeno Podjette Slovenske Zelezarne, Zelezarna Jesenice, Jesenice, Yugoslavia. (Plates, bars, sections and castings)

Zeljezara "Boris Kidric", Niksic, Yugoslavia. (Plates and castings)

Stockholm

Aktiebolaget Jarnforadling, Halleforsnas, Sweden. (Small castings)

Avesta Jernverks Aktiebolag, Avesta, Sweden. (Plates, sections and castings)

Boxholms A/B., Boxholm, Sweden. (Ingots, rolled slabs, blooms, billets, sections and bars)

Bulten-Kanthal AB.

Kanthal-Divisionen, Hallstahammar, Sweden.
(Ingots, billets, bars and castings)

Ramnäs Bruk-divisioner, Ramnäs, Sweden. (Rolling mills for bars)

Fagersta Bruks Aktiebolag, Fagersta, Sweden (Brukskoncernen).

Works: Fagersta. (Blooms, billets, forgings, rolled bars and electric resistance welded tubes)

Works: Forsbacka. (Blooms, billets, forged and rolled bars)

Works: Osterbybruk. (Castings, forgings and rolling mill for bars)

Hallstahammar Aktiebolag, Hallstahammar, Sweden. (Bars)

Hults Bruk A.B., Aby, Sweden. (Castings)

Kohlswa Jernverks Aktiebolag. (Ingots, forgings and castings)

APPENDICES TO CHAPTERS P AND Q

Stockholm-continued

Nordiska Armaturfabrikerna, A/B, Linköping, Sweden. (Castings)

Norrbottens Järnverk Aktiebolag, Lulea, Sweden. (Ingots, slabs, blooms and billets, bars and sections)

Oxelosunds Jarnverk, Oxelosund, Sweden. (Ingots, rolled slabs and plates)

SKF, Stål Hofors Bruk, Hofors, Sweden. (Billets, bars, forgings and thick walled tubes)

Sandvikens Jernverks Aktiebolag, Sandviken, Sweden. (Ingots, forgings, and tubes)

Smedjebackens Valsverks Aktiebolag, Smedjebacken, Sweden. (Bars, sections and ingots for re-rolling)

Stora Kopparbergs Bergslags A/B Specialstålverken) Vikmanshyttan, Sweden. (Forgings, bars and sections,

Stora Kopparbergs Bergslags Aktiebolag, Falun, Sweden.

Works: Domnarfvet. (Ingots, sections and plates)

Works: Söderfors. (Forgings, bars and sections)

Surahammars Bruks Aktiebolag, Surahammar, Sweden. (Plates, forgings and castings)

Svenska Jarnvagsverkstaderna, A/B, Linköping, Sweden. (Castings)

Svenska Kullagerfabriken, Aktiebolaget, Katrineholm, Sweden. (Castings)

Stuttgart

Streicher, M., Asperg/Wurtt, near Stuttgart, Germany. (Castings)

Sydney, N.S.W.

Bradford, Kendall, Ltd., Alexandria, Sydney, N.S.W. (Castings)

Commonwealth Steel Co., Ltd., Lidcombe, Sydney. (Castings)

Hadfields Steel Works, Ltd., Alexandria, Sydney, N.S.W. (Castings and forgings)

Industrial Steels, Ltd., Lidcombe, Sydney, N.S.W. (Castings)

Tampico

Fundidora de Fierro y Acero de Monterrey, S.A., Monterrey, N.L., Mexico. (Plates)

Toronto, Ontario

Algoma Steel Corporation, Ltd., Sault Ste. Marie, Ontario, Canada. (Plates, sections and bars)

Atlas Steels Company, Welland, Ontario, Canada. (Ingots and bars)

Black Clawson-Kennedy, Owen Sound, Ontario, Canada. (Castings)

Burlington Steel Company, Division of Slater Steel Industries, Ltd., Hamilton, Ontario, Canada. (Small sections and bars)

Canada Forgings Ltd., Welland, Ontario, Canada. (Forgings)

Dominion Foundries & Steel, Ltd., Hamilton, Ontario, Canada. (Ingots, plates and castings)

Toronto, Ontario-continued

Interprovincial Steel and Pipe Corporation Ltd., Regina, Saskatchewan, Canada. (*Plates*)

Steel Company of Canada, Hamilton, Ontario, Canada. (Bars and angles, plates and billets)

Welmet Industries, Ltd., Welland, Ontario, Canada. (Castings.)

Trieste

Bertoli S.p.A., Officine Fratelli Bertoli fu Rodolfo, Udine, Italy. (Castings, forgings, bars and sections)

Orion S.p.A., Porto Industriale, Trieste, Italy. (Forgings and castings)

S.A.F.A.U. Ferriere Acciaierie di Udine, Udine, Italy. (Ingots, forgings, blooms, bars and sections)

Safog, S.A., Fonderie Officine di Gorizia, Gorizia, Italy. (Castings)

Valencia

Astilleros Españoles S.A., Factoria de Manises, Valencia, Spain. (Castings and forgings)

Vizcaya, Altos Hornos de, S.A., Fabrica de Sagunto, Sagunto, Spain. (Ingots, plates, bars and sections)

Valenciennes

Blanc-Misseron, Société Française des Aciéries de, Quievrechain (Nord), France. (Ingots and castings)

Chiers, Société des Hauts-Fourneaux de la, Forges de Vireux Molhain, Vireux (Ardennes), France. (Bars and sections)

Cockerill-Ougree-Providence, Groupe D, Usines d'Hautmont (Nord), France. (Ingots and sections)

Dembiermont & Cie., Maurice, Hautmont (Nord), France. (Forgings)

Fonderies Grandry, S.A., Mohon (Ardennes), France. (Castings)

Fives-Lille-Cail, Société de.

Usine de Fives, Lille (Nord), France. (Forgings)
Usine de Denain, Denain (Nord), France. (Castings,
ingots, forgings, blooms, bars and sheets)

Haine - St. - Pierre et Lesquin, Aciéries de, Société Anonyme, Lesquin-lez-Lille (Nord), France. (Castings)

d'Hirson S.A., Aciéries, Hirson (Aisne), France. (Castings)

Maubeuge, Société Anonyme de la Fabrique de Fer de, Louvroil (Nord), France. (Ingots)

Meuse, Société Metallurgique de la, Forges et Aciéries de Stenay, Stenay, Meuse, France. (Castings)

Porter, H. K., (France), Aciéries Division Marpent, Marpent (Nord), France. (Castings)

Sambre et Meuse, Société Anonyme des Usines et Aciéries de, Usines de Feignies, Feignies (Nord), France. (Castings) Valenciennes-continued

Union Siderurgique du Nord et de l'Est de la France, "USINOR"

GROUPE A.

Usines de Denain, Denain (Nord), France. (Ingots, thin plates, and sections)

GROUPE B.

Usines de Valenciennes, Valenciennes, (Nord), France. (Ingots, forgings, blooms, bars and sections)

VALLOUREC.

Usine d'Anzin—Anzin (Nord), France. (Weldless rolled or drawn tubes)

Usine d'Aulnoye—Aulnoye (Nord), France. (Weld-less rolled or drawn tubes)

Valparaiso

Pacifico, Compania de Acero del, S.A., Talcahuano, Chile. (Ingots, plates, bars and sections)

Vancouver, B.C.

A.1. Iron & Steel Foundry Ltd., Vancouver, B.C., Canada. (Small castings)

C.A.E. Machinery Ltd., Vancouver B.C., Canada. (Small castings)

Consolidated Mining & Smelting Co. of Canada, Ltd., Trail, B.C., Canada. (Castings)

Esco Ltd., Port Coquitlam, B.C., Canada (Castings) Letson & Burpee, Ltd., Richmond, British Columbia, Canada. (Small castings)

Victoria Machinery Depot Co., Ltd., Victoria, B.C., Canada. (Castings)

Western Canada Šteel Ltd., (Vancouver Rolling Mills Ltd.,) Vancouver, B.C., Canada. (Sections and bars)

Venice (Mestre)

Bolzano, S.p.A. Acciaierie di, Bolzano. (Ingots, billets, bars and forgings)

Cantieri Navali del Tirrento e Riuniti, S.p.A., Ancona, Italy. (Small castings)

Flag S.p.A., Marcon (Mestre). (Small castings)

Gresele, Acciaierie Valbruna di Ernesto, Vicenza. (Castings, bars, sections and forgings)

"ITALSIDER" Alti Forni e Acciaierie Riunite Ilva e Cornigliano S.p.A., Stabilimento di Marghera. (Rolling mills for small sections and bars)

S.A.F.A.S.—Società Azionaria Fonderia Acciai Speciali, Tavernelle di Altavilla, Vicentina, (Vicenza). (Castings)

Vereeniging

Dunswart Iron & Steel Works, Ltd., Benoni, S. Africa. (Castings, ingots, billets, and small sections)

Scaw Metals, Ltd., Union Junction, Transvaal, S. Africa.
(Rivet bars, small rolled sections and castings)

South African Iron & Steel Industrial Corporation, Ltd.
"Iscor" Works, Pretoria, Transvaal, S. Africa.
(Ingots, billets, sections and forgings)

"Iscor" Works, Vanderbijlpark, Transvaal, S. Africa. (Ingots, billets, slabs and plates)

Union Steel Corporation of South Africa, Ltd., "Usco" Steel Works, Vereeniging, Transvaal, S. Africa. (Ingots, billets, small sections, castings and rivet bars) Vecor Heavy Engineering, Ltd., Vanderbijlpark, Transvaal, S. Africa. (Castings)

Vienna

WORKS IN AUSTRIA

Böhler, Gebr., & Co., Aktiengesellschaft, Vienna.

Works: Bohlerwerk, Low Austria. (Small forgings)

Works: Bruckbach, Low Austria. (Rolling mills
for sections and bars)

Works: Kapfenberg, Styria. (Ingots, castings, forgings, bars and plates)

Hubner-Vamag, Vereinigte Armaturenfabriken, Aktiengesellschaft, Vienna, Austria. (Castings)

Klinger, Rich., Aktiengesellschaft, Gumpoldskirchen, near Vienna. (Small castings)

Österreichisch - Alpine Montangesellschaft, Vienna.

Works: Donawitz, Styria. (Sections and strip)

Works: Kindberg, Styria. (Rolling mills for small sections, bars and strip)

Works: Traisen, Low Austria. (Castings)

Schoeller-Bleckmann Stahlwerke A.G., Vienna.

Works: Muerzzuschlag-Hoenigsberg, Styria. (Bars)
Works: Ternitz, Low Austria. (Castings, forgings
and bars)

Steirische Gusstahlwerke, A.G., Vienna.

Works: Judenburg, Styria. (Forgings and bars)

Vereinigte Österreichische Eisen-und-Stahlwerke A.G.

Works: Liezen, Styria. (Ingots for forgings, castings)

Works: Linz a.d. Donau, Upper Austria. (Plates,
forgings and castings)

Waagner-Biro Aktiengesellschaft, Vienna, Austria.

Works: Werk C., Vienna. (Castings)

Works in Czechoslovakia

Nová huť Klementa Gottwalda, národni podnik (New Metallurgical Works of Klement Gottwald, National Corporation), Ostrava-Kunčice. (Ingots)

Skoda, Oborový Podnik, Plzeň. (Castings and forgings)

Švermore Železiarne, národný podnik (Sverma's Iron Works, National Corporation), Podbrezová. (Ingots and plates)

Třinecké železárny velké Řijnové socialistické revoluce, národni podnik (Třinec Iron Works Great Socialistic October Revolution National Corporation), Třinec. (Ingots, sections, bars and castings)

Válcovny Trub a Železarny, národní podnik, (Tube Rolling Mills and Iron Works, National Corporation), Chomutov.

Works: Zelezárny Bílá Cerkev, národní podnik, Hrádek u Rokycan. (Ingots and bars) Works: Chomutov. (Seamless steel tubes)

Vítkovické Železárny Klementa Gottwalda, národni podnik (The Vitkovice Steel Works Klement Gottwald, National Corporation), Ostrava 10. (Castings, forgings, plates, sections, bars and seamless tubes)

Zelezárny a drátovny Bohumin, národni podnik (Iron Works & Wire Works Bohumin, National Corporation), Bohumin, Czechoslovakia. (Small sections and bars) Vienna-continued

WORKS IN HUNGARY

Ganz-Mavag Mozdony Vagon es Gepgyar, Budapest. (Castings and forgings)

K.G.M. Altalanos Gepipari Igazgatóság, Budapest. Works: Öntödei Vallalat 1. sz. Gyára, Budapest. (Castings)

K.G.M. Jarmuipari Igazgatóság, Budapest.

Works: Magyar Vagon-és Gépgyár, Györ. (Castings)

K.G.M. Vaskohászati Igazgatóság, Budapest.

Works: Lenin Kohászati Müvek, Miskolc-Diósgyör. (Ingots, slabs, sections, bars, castings and forgings) Works: Dunai Vasnü, Dunaujváros. (Ingots, slabs and plates)

Works: Dunai Vasmü, Lörinci Hengermüve, Budapest. (Rolling mill for plates)

Works: Ozdi Kohászati, Uzemek, Ozd. (Ingots, slabs, plates, sections and bars)

Vigo

Aceros de Galicia, Vigo, Spain. (Castings)

Whyalla

Broken Hill Proprietary Co., Ltd., Iron and Steel Works, Whyalla, S. Australia. (Ingots, castings, bars and sections)

Winterthur

Eisen-und Stahlwerke Oehler & Co. A.G., Aarau, Switzerland. (Castings)

Fischer, George, Ltd., Schaffhausen Switzerland. (Castings)

Fonderie de Fer et d'Acier Biel, Switzerland. (Castings) Sulzer Bros., Ltd., Winterthur, Switzerland. (Castings and forgings)

Von Roll A.-G., Gerlafingen, Switzerland. (Ingots, round bars and forgings)

Yokohama

Ando Iron Works Co., Ltd., Tokyo, Japan. (Small forgings)

Azuma Steel Casting Co. Ltd., Takaoka Works, Takaoka, Japan. (Castings)

Azuma Steel Works Ltd.

Azuma Plant, Tokyo, Japan. (Ingots for plate) Senju Plant, Tokyo, Japan. (Rolling mills for plates)

Daido Steel Co., Ltd., Shibukawa Works, Shibukawa, Japan. (Ingots, small forgings and bars)

Date Seiko Co., Ltd., Tokyo, Japan. (Castings)

Fukushima Seiko Co., Ltd., Fukushima, Japan. (Castings)

Funabashi Steel Works Ltd., Funabashi City, Chiba Prefecture, Japan. (Ingots and flat bars)

Hakodate Dock Co., Ltd., Hakodate Shipyard, Hakodate, Japan. (Small castings and forgings) Yokohama—continued

Haneda Pipe Works Co., Ltd., Tokyo, Japan. (Seamless tubes)

Hatakeyama Iron Works Co., Ltd., Komatsugawa. Works: Tokyo, Japan. (Small forgings)

Hitachi Ltd.

Hitachi Works, (Yamate Factory) Hitachi-shi Japan. (Castings)

Katsuta Works, Katsutashi, Inaragi-ken. (Ingots, forgings and castings)

Hokuriku Kogyo Co., Ltd., Sanjo Plant, Sanjo, Niigata Prefecture, Japan. (Small forgings)

Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan. (Ingots, forgings and castings)

Japan Special Steel Co., Ltd., Tokyo, Japan. (Ingots, forgings, blooms, billets and bars)

Japan Steel Works Ltd., Muroran Works, Muroran, Japan. (Ingots, forgings, castings and plates)

Johan Machinery Co. Ltd., Uchigo Factory, Fukushima Prefecture, Japan. (Castings)

Jonan Ironworks Co., Ltd., Haneda Works, Tokyo, Japan. (Small forgings)

Kakegawa Endo Iron Works Co., Ltd., Kakegawa, Japan. (Forgings)

Kanto Special Steel Works Ltd., Fujisawa, Kanagawa Pref., Japan. (Forgings)

Kawaguchi Kinzoku Kogyo Kabushiki Kaisha, Kawaguchi, Japan. (Castings)

Kawasaki Heavy Ind. Ltd., Crushing Plant Mfg. Division, Japan. (Castings)

Kawasaki Steel Corporation, Chiba Works, Chiba, Japan. (Slabs and plates)

Mitsubishi Heavy Industries Ltd., Yokohama Shipyard and Engine Works, 1-1 Midoricho, Nishi-ku, Yokohama, Japan. (Castings)

Mitsubishi Metal Mining Co., Ltd., Okegawa Plant, Saitama Prefecture, Japan. (Small castings)

Mitsubishi Steel Manufacturing Co., Ltd., Tokyo, Japan. Hirota Works, Fukushima Pref. (Castings) Tokyo Steel Works. (Billets, bars and small forgings)

Nakayama Steel Products Co. Ltd., Tsurumi Works, Tsurumi, Yokohama, Japan. (Ingots and plates)

Nippon Chuzo Kabushiki Kaisha, Kawasaki, Japan. (Castings)

Nippon Kokan Kabushiki Kaisha.

Asano Dockyard, Yokohama, Japan. (Small forgings)

Keihin Iron Works.

Mizue Plant. (Plates up to 12,5 mm in thickness)

Tsurumi Plant. (Ingots and plates)

Tubular & Structural Products Dept. (Tubes, bars and sections)

Nippon Stainless Steel Co., Ltd., Naoetsu Works, Niigata, Japan. (Ingots, forgings, castings and plates)

LLOYD'S REGISTER OF SHIPPING

Yokohama—continued

Nippon Steel Corporation.

Kamaishi Works, Kamaishi, Japan. (Sections and bars)

Kimitsu Works, Kimitsu, Japan. (Ingots and plates)

Muroran Works, Hokkaido, Japan. (Billets, sections and bars)

Tokyo Works, Japan. (Rolling mills for weldless, rolled or drawn tubes)

Nippon Yakin Kogyo Co., Ltd., Kawasaki, Japan. (Ingots, forgings, bars and thin plates)

Nittoku Metal Industry Co., Ltd., Tokyo, Japan. (Small forgings)

Oji Steel Co., Ltd.

Gunma Plant, Gunma Pref., Japan. (Ingots and bars) Kita-ku, Tokyo, Japan. (Flat bars)

Osaka Shipbuilding Co., Ltd., Taira Steel Works, Taira City, Fukushima Prefecture, Japan. (Castings)

Pacific Metals Company Limited.

Naoetsu Factory, Naoetsu, Niigata, Japan. (Ingots and castings)

Toyama Factory, Toyama City, Japan. (Ingots and forgings)

Riken Tanzo Co., Ltd., Maebashi Plant, Maebashi, Japan. (Small forgings)

Shimizu Kotetsu Co., Ltd., Tokyo, Japan. (Forgings)

Yokohama—continued

Shin Nippon Tanko K.K., Kawasaki, Japan. (Small forgings)

Sumitomo Metal Industries Kashima Steel Works, Kashima, Japan. (*Plates*)

Sunnan Iron Works Co., Ltd., Yaizu, Japan. (Forgings)
Tagajo Steel Casting Co., Ltd., Tagajo Miyagi Prefecture,
Japan. (Castings)

Takasaki Metal Industry Co., Ltd., Takasaki Plant, Takasaki, Japan. (Small castings)

Tohoku Special Steel Works Ltd., Sendai, Japan. (Ingots, small forgings, billets and bars)

Tokushu Seiko (Special Steel Mfg.) Co., Ltd., Kawasaki. Works: Kawasaki, Japan. (Ingots, forgings and bars)

Tokyo Kikai Kabushiki Kaisha, Oshima Cast Steel. Works: Tokyo, Japan. (Castings)

Tokyo Precision Forging Works Co., Ltd. (Tokyo Seitan Works Co., Ltd.), Ichikawa City, Chiba Prefecture, Japan. (Small forgings)

Tokyo Steel Casting Co., Ltd., Tokyo, Japan. (Castings)

Tokyo Tankosho Co., Ltd., Kawasaki Factory, Kawasaki, Japan. (Small forgings)

Toshin Steel Co., Ltd., Tokyo Steel Works, Tokyo, Japan. (Sections and ingots for forging and plates)

Tsurumi Steel Tube Co., Ltd., Yokohama, Japan. (Seamless and welded tubes)

Watanabe Steel Works Co., Ltd., Tokyo, Japan. (Castings)

APPENDICES TO CHAPTERS P AND Q

MANUFACTURERS OF ALUMINIUM ALLOYS

The following establishments have complied with the conditions contained in P 12 to P 14 of the Rules and are recognized by the Committee for the manufacture of aluminium alloys for shipbuilding purposes,

United Kingdom

Alcan Industries Ltd., Banbury. (Aluminium alloys and products)

Alcan Industries Ltd., Newport, Mon. (Aluminium alloys and products)

ALCOA Manufacturing (G.B.) Limited. (Aluminium alloys and products)

Aluminium Wire & Cable Co., Ltd., Port Tennant, Swansea. (Aluminium alloys and products)

Birmetals Ltd., Quinton, Birmingham. (Aluminium alloys and products)

James Booth Aluminium Ltd., Birmingham. (Aluminium alloys and products)

British Aluminium Co., Ltd., Falkirk. (Aluminium alloys and products)

British Aluminium Co., Ltd., Redditch Works, Birmingham. (Aluminium alloys and products)

British Aluminium Co., Ltd., Rheola Works, South Wales. (Aluminium alloys and products)

British Aluminium Co., Ltd., Bank Quay, Warrington. (Aluminium alloys and products)

High Duty Alloys Ltd., Winscales, Workington. (Aluminium alloys and products)

E. & E. Kaye, Ltd., Enfield, Middlesex. (Aluminium alloys and products)

Australia

Alcan Australia Limited.

Granville, N.S.W. Works. (Aluminium alloys and products) Kurri Kurri, N.S.W. Works. (Aluminium alloys)

Austria

Vereinigte Metallwerke Ranshofen-Berndorf A.G., Braunau am Inn. (Aluminium alloys and products)

Belgium

Ateliers Remi Claevs Lichtervelde. (Aluminium alloy products)

S.A. Sidal, Société de l'Aluminium, Duffel. (Aluminium alloys and products)

Sidal S.A., Burcht. (Aluminium alloy products)

Société Franco-Belge des Laminoirs et Tréfileries d'Anvers "LAMITREF", Hemiksem. (Aluminium alloy rivet bars)

Canada

Aluminum Company of Canada, Ltd. (No. 1 Plant), Shawinigan Falls, Quebec. (Aluminium alloy products) Aluminum Company of Canada, Ltd., Kingston, Ont. (Aluminium alloys and products)
Reynolds Extrusion Co., Ltd.

Plant No. 1, St. Therese, Quebec. (Aluminium alloys and products)

Plant No. 4, Oshawa, Ontario. (Aluminium alloys and products)

Denmark

Aluminord A/S, Glostrup, Copenhagen. (Aluminium alloys and products)

Finland

Oy Nokia A.B., Finska Kabelfabriken, Pikkala, (Aluminium alloys and products)

France

Société Cegedur G.P.

Le Blanc - Mesnil 93. (Aluminium alloys and products)

Chambery (Savoie). (Aluminium alloy products)

Faremoutiers (Seine & Marne). (Aluminium alloys and products)

Groupe Pechiney, Usine de Rive de Gier 42. (Aluminium alloy products)

Issoire (Puy de Dome). (Aluminium alloys and products)

Montreuil Belfroy. (Aluminium alloy products)

Soc. Cuivre et Alliages, Usine a Ham (Somme). (Aluminium alloys and products)

Germany

Aluminiumwalzwerke Singen G.m.b.H., Singen (Hohentwiel). (Aluminium alloys and products)

Otto Fuchs, Meinerzhagen. (Aluminium alloys and products)

Kabel-und Metallwerke Gutehoffnungshütte Aktiengesellschaft, Osnabriick. (Aluminium alloys and products)

Kaiser Aluminium-Werke G.m.b.H., Koblenz. (Aluminium alloys and products)

Reynolds Aluminiumwerke G.m.b.H., Nachrodt. (Aluminium alloys and products)

VAW Leichtmetall-werke G.m.b.H., Hannover. (Aluminium alloys and products)

Vereinigte Deutsche Metallwerke A.G., Frankfurt-Heddernheim. (Aluminium alloys and products)

Vereinigte Leichtmetall-werke G.m.b.H., Bonn. (Aluminium alloys and products)

Holland

N.V. Nederlandsche Aluminium Maats., Utrecht. (Aluminium alloys and products)

India

Indian Aluminium Co., Ltd., Alwaye, Kerala State. (Aluminium alloys and products)

Indian Aluminium Co., Ltd., Howrah, West Bengal. (Aluminium alloys and products)

LLOYD'S REGISTER OF SHIPPING

Italy

Lavorazione Leghe Leggere, Marghera (Venice).
(Aluminium alloys and products)

Montecatini Edison-Milan, Divisione Alluminio e Metalli, Feltre Works. (Aluminium alloys and products)

Trafilerie e Laminatoi di Metalli S.p.A., Milan. (Aluminium alloys and products)

Japan

Furukawa Aluminum Co., Ltd., Tokyo. (Aluminium alloys and products)

Kobe Steel Ltd., Chofu Plant, Shimonoseki. (Aluminium alloys and products)

Sumitomo Light Metal Industries Ltd., Nagoya Works, Nagoya. (Aluminium alloys and products)

Norway

Alnor Aluminium Norway A/S, Haugesund, Norway. (Aluminium alloys and products)

Alprofil, Raufoss. (Aluminium alloy products)

A/S Nordisk Aluminiumindustri, Oslo. Hoyanger Works. (Aluminium alloys) Holmestrand Works. (Aluminium alloy products)

Poland

Walcownie Metali "Dziedzice".

Czechowice-Dziedzice. (Aluminium alloy sections, bars and tubes)

Zaklady Metali Lekkich "Kety", Kety. (Aluminium alloy, sections and tubes)

Spain

Aluminio de Galicia S.A.

Amorebieta Works. (Aluminium alloys and products)

Spain-continued

La Coruña Works, (Aluminium alloys and products)

Sabinanigo Works. (Aluminium alloys and products)

Aluminio Iberico, S.A., Alicante. (Aluminium alloys and products)

Eduardo K. L. Earle, Lejona. (Aluminium alloys and products)

Sweden

A/B Svenska Metallverken, Finspong. (Aluminium alloys and products)

Switzerland

Aluminium Press & Walzwerk A. G., Munchenstein.
(Aluminium alloys and products)

Aluminium S.A., Menziken. (Aluminium alloys and products)

Swiss Aluminium Ltd., Chippis. (Aluminium alloys and products)

U.S.A.

Alcan Aluminum Corporation, Fairmount, West Virginia, U.S.A. (Aluminium alloys and products)

Alcan Aluminum Corporation, Oswego, New York.
(Aluminium alloys and products)

Aluminum Company of America.

Davenport Works. (Aluminium alloys and products)
Lafayette Works. (Aluminium alloys and products)
Massena Works. (Aluminium alloys and products)

Yugoslavia

Impol, Industrija Metalnih Polizdelkov, Slovenska Bistrica. (Aluminium alloys and products)

Tvornica Lakih Metala "Boris Kidric", Sibenik. (Aluminium alloys and products)

APPENDICES TO CHAPTERS P AND Q

MANUFACTURERS OF STEEL WIRE ROPE

The following establishments have complied with the conditions contained in P 9 of the Rules and are recognized by the Committee for the manufacture of steel wire ropes.

United Kingdom

British Ropes Ltd., Doncaster.

British Ropes Ltd., Gateshead-on-Tyne.

British Ropes Ltd., Glasgow.

British Ropes Ltd., London.

British Ropes Ltd., Retford.

British Ropes Ltd., (Webster Ropes), Sunderland.

Bruntons (Musselburgh) Ltd., Musselburgh.

Crawhall, Joseph. & Sons Ltd., Gateshead-on-Tyne.

Dawson & Usher Ltd., Sunderland.

Excelsior Ropes Group,

Comprising:-

Excelsior Ropes Ltd.,

Western Avenue,

Geo. Elliott & Co., Ltd.,

Cardiff. D. Morgan Rees & Sons Ltd.,

Firth Cleveland Ropes Ltd., Sheffield.

Frew Bros. Ltd., Coatbridge.

Glover Bros. (Mossley) Ltd., near Manchester.

The Gourock Ropeworks, Glasgow.

Hall's Barton Ropery Co., Ltd., Hull.

Hood Haggie, R., & Son, Ltd., Newcastle upon Tyne.

John I. Hopper Ltd., Thornaby-on-Tees.

Latch & Batchelor Ltd., Birmingham.

Martin, Black & Co. (Wire Ropes), Ltd., Coatbridge.

Overton Bros. Wire Ropes Ltd., Hull.

Rylands Bros., Ltd., Warrington.

Scottish Wire Rope Co., Ltd. (John I. Hopper Ropes),

near Glasgow.

Shaw, John, Ltd., Worksop.

Whitecross Co., Ltd., Warrington.

Argentina

Establecimientos Metalurgicos Santa Rosa S.A., Buenos

Felix Simon S.A.C.I.F., Buenos Aires.

Australia

Australian Wire Rope Works Pty. Ltd., Newcastle, N.S.W.

Austria

Felten & Guilleaume Fabrik Elektrischer Kabel, Vienna and Bruck an der Mur.

Joh. Pengg, Draht-und Walzwerke, Thörl bei Aflenz, Steiermark.

St. Egydyer Eisen-und Stahl-Industrie-Gesellschaft, St. Aegyd am Neuwalde.

Teufelberger, K., Drahtseilwerke, Wels, Upper Austria.

Belgium

Anglo-Continental Ropes, Gilly.

"Cabcord" (Société Générale de Cablerie et Corderie), Hamme s/durme.

"Cabcord" (Société Générale de Cablerie et Corderie), Renory.

Cableries Namuroises S.A., Jambes.

Cableries & Corderies du Hainaut, S.A., Dour, near Mons.

Gonzalez Cock S.A., Lokeren.

Le Lis, S.A., Hamme-sur-Durme.

Van Praet-Dansaert, Baasrode.

Cia. Industrial e Mercantil de Artefatos de Ferros, Sao Paulo.

Canada

Greening Donald Ltd., Hamilton, Ontario.

Greening Donald Ltd., Midland, Ontario.

Wire Rope Industries of Canada Ltd. (Canada Wire Ropes Ltd.), Smith Falls, Ontario.

Wire Rope Industries of Canada Ltd., Vancouver, B.C.

Chile

Productos de Acero, Santiago.

Denmark

Jacob Holm & Sønners Fabriker, A/B., Copenhagen. Randers Rebslaaeri A/S., Randers.

Finland

Oy Teräsköysi, Hämevaara, Nr. Helsinki.

France

Cablerie Saint-Moritz, Reichshoffen (67).

Société Anonyme des Hautes Fourneaux de la Chiers, Departement des Trefileries & Cableries, Le Havre.

Laminoirs-Tréfileries-Cableries de Lens, Lens.

Tréfileries de Chatillon-Gorcy S.A. Usine de Sainte-Colombe-sur Seine-21.

Germany

Ahlers, C. G., Hanf-u. Drahtseilfabrik, Bremerhaven.

Arbed S.A., Arbed-Felten & Guilleaume, Vereinigte Drahtwerke, Koln-Mulheim.

Bertram, J., K.G. Drahtseilwerk, Soest.

LLOYD'S REGISTER OF SHIPPING

Germany-continued

Braucke, Adolf vom. A.G., Ihmerterbach.

Bremer Draht-und Seilindustrie G.m.b.H., Bremen-Hemelingen.

Drahtseilerei Gustav Kocks G.m.b.H., Mülheim (Ruhr)—Broich.

Drahtseilwerke G.m.b.H., Bremerhaven.

Gempt, J. H., Lengerich/Westf.

Hamburger Drahtseilerei G.m.b.H., Bad Oldesloe.

Georg Heckel G.m.b.H., Draht-und Drahtseilfabrik, Saarbrucken.

Klockner - Werke A.G. Dusseldorfer Drahtindustrie, Dusseldorf.

Norddeutsches Drahtseilwerk, A. Brinkmann, Syke.

Seilindustrie Ernst Deifuss, Unna/Westf.

Seilwerke Heinrich Puth K.G., Blankenstein, Ruhr.

Vereinigte Drahtseilwerke G.m.b.H., Dortmund.

Vornbäumen, J. & W., K.G., Bad Iburg.

Westdeutsche Seilindustrie Paul Stoessel, Osterrath b/Dusseldorf.

Westfälische Drahtindustrie, Hamm.

Westfälische Union A.G., Drahtseilerei, Werk Gelsenkirchen.

Westfälische Union A.G., Lippstadt.

Westfälische Union A.G., für Eisen und Drahtindustrie, Drahtseilwerk Oesede.

Westfalische Union, Werk Neheim.

Wolf, Gustav, Gütersloh.

Greece

Greek German Wire Rope Industry, Nea Ionia, Volos.

Holland

Den Haan Staalkabelfabriek N.V., Gorinchem. Vereenigde Touwfabrieken, Leiderdorp.

Hong Kong

Hong Kong Steel Ropes Ltd., Kowloon.

India

Bombay Wire Ropes Ltd., Bombay.

Chaudhri Wire Rope Industries Ltd., Lahore.

Eldee Wire Ropes Pvt. Ltd., Bombay.

Fort William Company Limited, Steel Wire & Rope Division, Calcutta.

Mohatta & Heckel Ltd., Khopoli.

South India Wire Ropes Ltd., Kerala State.

J. K. Steel Ltd., Calcutta.

United Wire Ropes Ltd., Bombay.

Usha Martin Black (Wire Ropes) Ltd., Asian Wire Ropes, Ranchi.

Israel

Wire Rope Works Messilot Ltd., Doar Na Gilboa.

Italy

Acciaierie Ferriere Lombarde Falck, Sesto San Giovanni. Giuseppe & Fratello Redaelli S.p.A.,—Gardone val

Trompia (Brescia), Brescia.

Industrie Metallurgiche Piemontesi, Susa.

Ing. Guido Scolari (Soc., Acc., Semp.), Milan.

Societa Italiana Derivati Vergella, S.p.A. (D.E.R.I.V.E.R.), Sezione di Torre Annuziata.

Stabilimenti G. Fornara & Co., Turin.

Japan

Ako Rope & Wire Mfg. Co., Ltd., Sakoshi.

Daido Wire Rope Mfg. Co., Ltd., Osaka.

Igeta Wire Rope Co. Ltd., Izumisano.

Kasuga Seiko K.K., Osaka.

Kawasaki Steel Corporation, Wire Rope and Welding Rod Plant, Chiba.

Kokoku Steel Wire Ltd., Niigata.

Kokoku Steel Wire Ltd., Osaka.

Kokoku Steel Wire Ltd., Tokyo.

Nankai Sensyu Steel Wire & Rope Co., Ltd., Kaizuka.

Nippon Steel Wire & Wire Rope Co., Ltd., Osaka.

Nishida Wire Rope Mfg. Co., Ltd., Osaka.

Shinko Wire Co., Ltd., Amagasaki, Japan.

Shinko Wire Co., Ltd., Osaka, Japan.

Showa Wire Rope Mfg. Co., Ltd., Osaka.

Tatsumi Rope Mfg. Co., Ltd., Osaka.

Teikoku Sangyo Co., Ltd., Osaka.

Tokyo Rope Mfg. Co., Kokura.

Tokyo Rope Mfg. Co., Osaka.

Tokyo Nope Mig. Co., Osaka.

Tokyo Rope Mfg. Co., Ltd., Ibaragi Prefecture.

Korea

Korea Iron & Steel Wire Co., Ltd., Pusan.

Mexico

Cables Mexicanos S.A., Mexico.

Norway

Norsk Staaltaugfabrik, Trondheim. Stål og Tau A/S Avd. Mandal, Mandal. Stål og Tau A/S Avd. Tonsberg Reperbane.

Poland

Fabryka Lin i Drutu, Bytom Karb. Sosnowiecka Fabryka Lin i Drutu, Sosnowiec.

Portugal

Cordoaria Lisbonense, Lisbon. Quintas and Quintas, Povoa do Varzim. Rodrigues d'Oliveira, M., Sa & Fos, Ltda., Oporto.

APPENDICES TO CHAPTERS P AND Q

South Africa

Haggie Rand Ltd., Johannesburg.
Subsiduary Companies
Haggie, Son & Love (1936) Ltd., Jupiter Rope
Works, Cleveland.
Rand Ropes, Ltd., Germiston.

Spain

Forjas y Alambres de Cadagua, Bilbao. Franco Espanola de Alambres, S.A., Bilbao. "Nueva Montana Quijano", S.A., Santander. Trenzas y Cables de Acero S.A., Barcelona.

Sweden

Garphytte Bruks A/B., Garphyttan. Gunnebo Bruks A/B Varberg.

Sweden-continued

Lesjofors A/B., Lesjofors.
Stallinefabriken, David Ahlquist A/B., Roslags-Nasby.
Uddeholms A/B., Blombacka Bruk, Lindfors.

United Arab Republic

Copper Works, Hagar el Nawatia, Alexandria.

United States of America

The Wire Rope Corporation of America, St. Joseph, Missouri.

Yugoslavia

Novosadska Fabrika Kabela, Novi Sad. "Otocanka", Zadar.

ALTERNATION TO UNAPPERS P AND Q

PROVING ESTABLISHMENTS

The following establishments have been recognized by the Committee for the testing of anchors and chain cables in accordance with the Society's Rules. Anchors and chain cables intended for ships of United Kingdom Registry must be tested at establishments certified under the terms of the United Kingdom Anchors and Chain Cables Act, 1967.

Argentine

Direction General de Administracion Naval, Buenos Aires, Argentine.

Australia

Falkiner Chains Pty. Ltd., Brisbane, Queensland (for testing chain cables up to 250 tons).

Austria

Ferdinand Freiherr v. Helldorff & Otto Rothart Kettenwerk Brückl, Brückl, Carinthia.

Steirische Kettenfabriken Pengg-Walenta Kommanditgesellschaft, Werk Hansenhütte, Kapfenberg-Hansenhütte, Styria.

Belgium

Adh. Demanet, Gosselies (for testing chains up to 300 tons).

Béliard, Murdoch & Co., Antwerp (for testing anchors and chain cables up to 100 tons).

Mercantile Marine Engineering & Graving Dock Co., Antwerp.

Usines et Aciéries Allard S.A., Mont-sur-Marchienne (for testing anchors only).

Brazil

Acos Villares, Sao Paulo (for testing anchors only).

Canada

Canada Chain & Forge Co., Ltd., Granville Island Vancouver, B.C.

Dominion Chain Co., Ltd., Stratford, Ontario. Drummond, McCall & Co., Ltd., Quebec.

Finland

Fiskars A.B., Loimaa.

Oy Wärtsilä A/B., Dalsbruk, Helsingfors (for testing anchors up to 150 tons and chain cables up to 250 tons).

France

Carlier et Cie., St. Amand-les-Eaux (Nord).

Davaine, Fils et Cie., St. Amand-les-Eaux (Nord) (for testing chain cables up to 132 tons).

Ets. Marit, St. Amand-les-Eaux (Nord).

Manufacture de Chaines et Ancres de Saint-Amand, Etablissements Sirot-Mestreit and Dorémieux Reunis, Saint-Amand-les-Eaux (Nord),

Paoli, J., & Co., Marseilles.

Société des Forges des Fresnes, Fresnes-sur-Escaut (Nord) (for testing chain cables up to 150 tons).

Veille, A., & Co., Le Havre.

Germany

Blohm & Voss A.G., Hamburg.

Dortmunder Kettenfabrik Bernhard Mester, Wetterstr. 10, Dortmund.

Duisberger Kettenfabriek und Hammerwerk, H d'Hone, Duisburg.

Eisenwerk und Apparatebau Gebr. Knauer, Abteilung Hammerwerk Heuss (Mannheim).

Fröndenberger Kettenfabrik, Heinrich Prünte, Frondenberg-Ruhr (for testing chain cables up to 120 tons.)

Wilhelm Gröhnke, Hamburg.

Hoesch Hüttenwerke A.G., Werk Phoenix Hörde, Dortmund-Hörde (for testing anchors only).

Howaldtswerke A.G., Hamburg.

Joto-Werk Josef Topp, Kettenfabrik, Warmen (Ruhr).

Kettenfabrik Kalthof, August Thiele; and August Thiele G.m.b.H., Fabrik für Ketten und Kettenforderer, Kalthof, near Schwerte-Ruhr.

Kettenwerke Schlieper, Grune, Westphalia.

Theile, J. D., Schwerte-Ruhr.

LLOYD'S REGISTER OF SHIPPING

Holland

Koninklijke Nederlandsche Grofsmederij, Leiden.

N.V. Anker-& Kettingfabriek "Schiedam" (Managing Director: P. Th. Verhoeff), Schiedam.

Hong Kong

The Taikoo Dockyard & Engineering Co. of Hong Kong Ltd.

Hungary

Kohó-és Gépipari Miniszterium, Budapest, Works: Kéziszerszámgyár, Budapest.

India

The Commissioners for the Port of Calcutta, Calcutta.

Italy

Acciaieria e Ferriera del Caleotto S.p.A., Lecco.

Acciaierie Weissenfels, Catenificio, Fusine di Valromana, Udine (for the testing of small chains only).

Neptunia S.r.L., Genoa.

Japan

Hamanaka Chain Manufacturing Co., Ltd., Himeji.

Japan Mechanical Chain Manufacturing Co., Ltd., Osaka.

Kotobuki Kogyo Co. Ltd., Hiro Works, Kure.

Koyo Chain Manufacturing Co., Ltd., Osaka.

Onomichi Anchor Manufacturing Co., Ltd., Onomichi (for testing anchors only).

Osaka Chain & Machinery Manufacturing Co., Ltd., Kaizuka Works, Osaka.

Toa Seisa Co., Ltd., Himeji.

Tokiwa Kogyo Co., Ltd., Himeji.

Tokyo Chain & Anchor Co., Ltd., Tokyo.

Malta

Malta Drydocks, The Docks, Malta G.C.

Norway

Norsk Kjettingindustri A/S, Mandal.

Poland

Stocznia im. Komuny Paryskiej, Gdynia.

Zaklady Mechaniczne im. Gen. K. Swierczewskiego, Elblag.

Singapore

Sembawang Shipyard (Pte) Ltd.

South Africa

Cotts Steel Industries (Pty.) Ltd., Johannesburg.

McKinnon Chain (South Africa) (Pty.) Ltd., Vereeniging, Transvaal.

Spain

Cadenas y Forjádos, S.A., J. M. Olavarri, Bilbao. Works: Lejona, Bilbao.

Don Ciriaco Rodriguez Dorado, Barcelona (for testing chain cables up to 30 tons).

Forjas de San Martin de Pedro Framis, Barcelona (for testing chains up to 16 tons).

Vicinay, S.A., Deusto.

Sweden

Bergvik & Ala A/B, Ljusne-Industrierna, Ljusne.

Gunnebo Bruks Aktiebolag, Gunnebobuck, Västervik (for testing chains up to 75 tons).

Jarnbirger A/B, Orsa.

Ramnäs Bruks Aktiebolag, Ramnäs.

Statens Provningsanstalt (Government Establishment), Stockholm.

Turkey

Gemi Zincir Sanayii Kollektif Sirketi, Istanbul.

United Kingdom

Brown, Lenox & Co., Ltd., Pontypridd, Mon.

Griffin-Woodhouse Ltd., Cradley Heath, Staffs.

Lloyd's (Brierley Hill) Ltd., Brierly Hill, Staffs.

Lloyd's British Testing Co. Ltd., Low Walker-on-Tyne, Northumberland.

Lloyd's British Testing Co. Ltd., Netherton, (near Dudley), Worcs.

Lloyd's Scottish Testing Co. Ltd., Burnbank, Hamilton, Lanark.

Lloyd's South Wales Testing House Co. Ltd., Cardiff, Glam.

Norbrit-Pickering Ltd., Coatbridge, Lanark.

United States

Baldt Anchor Chain & Forge Division of Baldt Corp., Chester, Pa.

Baldt Anchor Chain & Forge Division of Baldt Corp., Fieldsboro, N.J.

Johnson-Farmer Chain Co., Lebanon, Pa.

Washington Chain & Supply Co., Seattle, Washington.

Yugoslavia

Tovarna Verig, Lesce pri Bledu.

APPENDICES TO CHAPTERS P AND Q

ELECTRICALLY WELDED STEEL CHAIN CABLES

and

CAST STEEL CHAIN CABLES

The following establishments have complied with the requirements for manufacture of electrically welded and cast steel chain cables and have been recognized by the Committee:—

- Grade U 1 (a) Flash butt welded chain cables of mild steel having a tensile breaking strength of 31 to 41 kg/mm² (19·7 to 26·0 ton/in²).
- Grade U 1 (b) Flash butt welded chain cables of mild steel having a tensile breaking strength of 41 to 50 kg/mm² (26·0 to 31·7 ton/in²).
- Grade U 2 (a) Flash butt welded or drop forged special quality steel having a tensile breaking strength of 50 to 65 kg/mm² (31 · 7 to 41 · 3 ton/in²).
- Grade U 2 (b) Cast steel having a minimum tensile breaking strength of 50 kg/mm² (31.7 ton/in²).
- Grade U 3 (a) Flash butt welded or drop forged extra special quality steel having a minimum tensile breaking strength of $70 \text{ kg/mm}^2 (44 \cdot 4 \text{ ton/in}^2)$.
- Grade U 3 (b) Cast steel having a minimum tensile breaking strength of 70 kg/mm² (44·4 ton/in²).

Note: Before acceptance on classed ships, chain cables must be tested on a chain cable testing machine recognized by the Society.

Firm	GRADE & TRADE NAME (IF ANY)	MAXIMUM DIAMETER	Surveying District
United Kingdom			
Beal & Son (Cable Makers) Ltd., Cardiff.	U 1 (a), U 1 (b) & U 2 (a) U 2 (a) (Meyer, Roth and Pastor)	4 in 13 in	Cardiff
Bradney Chain & Engineering Co. Ltd., Quarry Road, Dudley, Worcs.	U 1 (b) (Short link)	½ in	Birmingham
Brown, Lenox & Co. Ltd., Pontypridd.	U 2 (b)	3 in	Cardiff
Griffin-Woodhouse Ltd., Cradley Heath, Staffs.	U 2 (a)	$2\frac{3}{16}$ in	Birmingham
Lloyds (Brierley Hill) Ltd., Brierley Hill, Staffs.	U 1 (a) & U 1 (b) U 2 (a) (Tayco)	4½ in 4½ in	Birmingham
	U 2 (a) (New Process Tayco)	3.5 in	
	U 3 (a)	4 in	
Norbrit-Pickering Ltd., Wishaw, Lanarkshire.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	$\frac{4_{\frac{1}{8}} \text{ in}}{4_{\frac{1}{2}} \text{ in}}$	Glasgow
Parsons Chain Co. Ltd., Stourport-on-Severn.	U 1 (a), U 1 (b) & U 2 (a) (Short link)	14 in	Birmingham
Wheway Watson Ltd., Bellshill, Lanarkshire.	U 2 (a) (Short link)	7 in	Glasgow
Wheway Watson Ltd., Walsall Works, Walsall.	U 1 (a) U 1 (b) (Short link)	7 in 11 in	Birmingham

LLOYD'S REGISTER OF SHIPPING

Firm	Grade & Trade Name (if any)	MAXIMUM DIAMETER	Surveying District
Australia Manual Richard			
Falkiner Chains Pty. Ltd., Brisbane.	U 1 (a) U 1 (b) (Short link)	3-3 in 3 in	Brisbane
	U 2 (a)	3-3 in	
Austria			
Ferdinand Freiherr v. Helldorff & Otto Rothart Kettenwerk Brückl, Brückl.	U 1 (a) (Short link)	26 mm	Vienna
Steirische Kettenfabriken Pengg-Walenta Kommanditgesellschaft, Styria.	U 1 (a) U 1 (b) & U 2 (a)	44 mm 41 mm	Vienna
Belgium			
Adh-Demanet, Gosselies.	U 1 (a), U 1 (b) & U 2 (a)	76 mm	Antwerp
Finland			
Fiskars A.B., Loimaa.	U 1 (a)	36 mm	Abo
Oy Wartsilä A.B., Dalsbruk Works, Dalsbruk.	U 1 (a), U 1 (b) & U 2 (a)	64 mm	Abo
France	Red Strategy 45		
M. Carlier & Cie., StAmand-les-Eaux (Nord).	U 1 (a) & U 1 (b)	30 mm	Valencienne
Davaine Fils et Cie., StAmand-les-Eaux (Nord).	U 1 (a) & U 1 (b)	30 mm	Valencienne
Etablissements Marit, Saint-Amand-les-Eaux (Nord).	U 1 (a) & U 1 (b)	44 mm	Valencienne
Manufacture de Chaines et Ancres de Saint-Amand, Etablissements Sirot-Mestreit and Dorémieux Reunis. Saint-Amand-les-Eaux (Nord.)	U 1 (a), U 1 (b) & U 2 (a) U 1 (a), U 1 (b) & U 2 (a) (Etaifix)	100 mm 123,5 mm	Valencienne Valencienne
Soc. des Forges de Fresnes, Fresnes sur Escaut (Nord).	U 1 (a) & U 1 (b) U 2 (a)	65 mm 60 mm	Valencienne
A. Veille et Cie., Le Havre.	U 1 (a), U 1 (b) & U 2 (a) U 1 (a), U 1 (b) & U 2 (a) (Monobloc)	100 mm 91 mm	Havre
Germany and a series of the control	Waller deservices section		
Dortmunder Kettenfabrik B. Mester, Dortmund.	U 1 (a) & U 2 (a)	69 mm	Dortmund
Joto-werk, Josef Topp Kettenfabrik, Warmen (Ruhr).	U 1 (a) & U 1 (b) U 2 (a)	68 mm 62 mm	Dortmund
Kettenfabrik Kalthof, August Thiele; August Thiele G.m.b.H. Fabrik für Ketten und Kettenforderer, Kalthof, near Schwerte-Ruhr.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	105 mm 120 mm	Dortmund

APPENDICES TO CHAPTERS P AND Q

Firm	GRADE & TRADE NAME (IF ANY)	MAXIMUM DIAMETER	Surveying District
Germany—continued			
Kettenwerke Schlieper, Grune-Westfalen.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	110 mm 120 mm	Dortmund
Theile, J. D., Schwerte-Ruhr.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	92 mm 56 mm	Dortmund
Holland			
Anker-En Kettingfabriek "Schiedam", Schiedam.	U 2 (a)	78 mm	Rotterdam
Koninklijke Nederlandsche Grofsmederij, Leiden.	U 1 (a), U 1 (b) & U 2 (a) (Ego)	93,5 mm	Rotterdam
	U 1 (a) & U 1 (b) (Eldam)	75 mm	
	U 1 (a), U 1 (b) & U 2 (a)	105 mm	
India			
Indian Chain Manufacturing Co., Calcutta.	U 2 (a)	54 mm	Calcutta
Italy			
Acciaieria e Ferreira del Caleotto, Lecco.	U 1 (a), U 1 (b) & U 2 (a)	90 mm	Milan
Japan			
Hamanaka Chain Manufacturing Co. Ltd., Himeji.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	150 mm 155 mm	Kobe
Japan Mechanical Chain Manufacturing Co. Ltd., Osaka.	U 2 (a) (Kikai)	64 mm	Kobe
	U 1 (a), U 1 (b) & U 2 (a) (Flash welded)	58 mm	
Koyo Chain Mfg. Co. Ltd., Osaka.	U 1 (a), U 1 (b) & U 2 (a)	42 mm	Kobe
Osaka Chain & Machinery Mfg. Co. Ltd., Osaka	U 2 (a) & U 2 (b) U 3 (a) & U 3 (b)	146 mm 127 mm	Kobe
Tokyo Chain & Anchor Co. Ltd., Tokyo.	U 1 (a), U 1 (b), U 2 (a) & U 2 (b)	150 mm	Yokohama
	U 3 (a)	120 mm	
ľokiwa Kogyo Co. Ltd., Himeji.	U 2 (a)	64 mm	Kobe
Norway			
Norsk Kjettingindustri A/S, Mandal.	U 1 (a) (Short link)	25 mm	Oslo
	U 1 (a) (Stud link)	32 mm	
	U 2 (a) (Stud link)	27 mm	

LLOYD'S REGISTER OF SHIPPING

FIRM	GRADE & TRADE NAME (IF ANY)	MAXIMUM DIAMETER	Surveying District
South Africa			
Cotts Steel Industries (Pty) Ltd., Johannesburg.	U 1 (a), U 1 (b) & U 2 (a)	13 in	Vereeniging
McKinnon Chain (South Africa) (Pty) Ltd., Vereeniging.	U 1 (a) (Short link)	3 in	Vereeniging
min 85 (a) 8.55	U 1 (a), U 1 (b) & U 2 (a)	2 in	
Spain			
Cadenas y Forjados, Bilbao.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	85 mm 76 mm	Bilbao
Don Ciriaco Rodriguez Dorado, Barcelona.	U 1 (a) & U 1 (b) U 2 (a)	30 mm 26 mm	Barcelona
Vicinay S.A., Deusto.	U 1 (a) & U 1 (b) U 2 (a) U 3 (a)	95 mm 114 mm 114 mm	Bilbao
Sweden			
Bergvik & Ala AB, Ljusne-Industrierna, Ljusne	U 1 (a) & U 1 (b) U 2 (a) U 3 (a)	92 mm 120 mm 155 mm	Stockholm
Gunnebo Bruks Aktiebolag, Gunnebobruk.	U 1 (a) & U 1 (b)	16 mm	Stockholm
Jarnbirger A/B, Orsa.	U 1 (a), U 1 (b) & U 2 (a)	55 mm	Stockholm
Ramnäs Bruks Aktiebolag, Ramnäs.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	98 mm 152 mm	Stockholm
United Arab Republic			
El Nasr Forgings, Cairo.	U 1 (a)	38 mm	Alexandria
United States of America			
Baldt Anchor Chain & Forge Division of Baldt Corp., Chester, Pennsylvania.	U 2 (a) (Weld in alternate links)	5 in	Philadelphia
	U 2 (a) (Flash welded)	41 in	
Yugoslavia			
Tovarna Verig, Lesce.	U 1 (a), U 1 (b) & U 2 (a) U 3	100 mm 100 mm	Rijeka
The same of the sa			

Chapter R

PROVISIONAL RULES AND GUIDANCE NOTES

Explanatory Notes

PROVISIONAL RULES give requirements which have been framed primarily for the initial regulation of ship and machinery applications in process of development; they are subject to continuous review.

GUIDANCE NOTES are intended as recommendations to designers, based on good practice, in matters for which the present state of knowledge does not justify precise requirements.

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R (A)—PROVISIONAL RULES FOR THE USE OF METHANE GAS AS FUEL FOR THE PROPULSION OF METHANE TANKERS

Section 1

General

101 In methane tankers the methane "boil-off" may be used as fuel for propulsion services subject to compliance with the following Rules or equivalents; it is not to be used for firing auxiliary or domestic boilers or for auxiliary engine services.

102 These provisional Rules are based on the assumption that the pressure of the gas supply to the machinery space will not exceed 1 kg/cm² (15 lb/in²) gauge for boilers, and 7 kg/cm² (100 lb/in²) gauge for oil engines, and that the gas temperature in both cases will be approximately ambient. Where higher pressure or temperature conditions are proposed the arrangements will be specially considered.

It is also assumed that adequate oil fuel bunkers will always be carried and that the ship will not be entirely dependent on the methane "boil-off" for fuel requirements during any voyage.

Plans

103 The following plans are to be submitted for consideration:—

General arrangement of plant.

Gas piping system, together with details of interlocking and safety devices.

Gas heaters.

Gas compressors and their prime movers.

Gas storage pressure vessels.

Gas and oil fuel burning arrangements.

Equipment for Heating, Compressing and Storing Methane Gas

104 The methane gas is to be heated and compressed outside the machinery space. If the gas is stored in a pressure vessel the latter is also to be located outside the machinery space.

- 105 Gas heaters and compressors, of watertight construction, may be installed on the open deck provided they are suitably located and protected from mechanical damage. Alternatively, the heaters and compressors may be installed in a well ventilated compartment outside the machinery space. This compartment is to be treated as a dangerous space to which the requirements of M 16 for electrical equipment are applicable.
- 106 If steam is adopted as the heating medium the steam supply to the heaters is to be automatically controlled by the discharge temperature of the methane from the heaters, and the steam drains are to be led to a vented drain tank outside the machinery space. The vents are to be led to a safe position.
- 107 The prime movers for the gas compressors are to be regulated to maintain a positive suction pressure and arranged to stop automatically if the pressure on the suction side of the compressors is lower than 0,035 kg/cm² (0.5 lb/in²) gauge or other approved positive pressure appropriate to the cargo tank system. They are also to be capable of being stopped, in emergency, from suitable positions on deck and in the machinery space.
- 108 Gas compressors of the piston type are to be fitted with relief valves discharging to a safe position. The relief valves are to be so proportioned and adjusted that the accumulation with the outlet valves closed will not exceed 10 per cent of the maximum working pressure.
- 109 The suction and discharge connections to the compressors are to be fitted with isolating valves and flame arresters.
- 110 Pressure vessels for storing methane gas are to be of approved design and fitted with pressure relief valves discharging to atmosphere in a safe position.

Ventilation of Machinery Spaces

111 Efficient arrangements are to be provided for the thorough ventilation of the machinery space under all climatic conditions and are to include a monitoring system with visual and audible warnings to detect gas leaks.

Gas Supply Pipes in Machinery Spaces

112 The gas supply lines in the machinery space are to be fitted in trunks or casings which are maintained by exhaust fans at a pressure slightly below that prevailing in the machinery space. The fans are to be of a type in which the electric motor is outside the ducting. The air discharge is to be led to a safe position and is to be monitored for methane leakage. Alternatively, the supply lines may

be contained in trunks or casings pressurised by an inert gas at a pressure appreciably higher than the methane gas pressure. The gas supply lines are to be located remote from the ship's sides. Indicators of the trunk ventilation or pressurisation are to be provided.

- are to have all-welded joints so far as practicable, and are to be tested in place by hydraulic pressure to 7 kg/cm² (100 lb/in²) or twice the working pressure, whichever is the greater. Subsequently, the lines are to be tested by air at the working pressure using "Soapy Water", or equivalent, to verify that all joints are absolutely tight.
- 114 Provision is to be made at a suitable position on deck for shutting off the gas supply before it enters the machinery space.

Purging Arrangements

115 Arrangements are to be made for purging the complete methane system with an inert gas or steam before and after pipes, auxiliaries, etc., are opened up for inspection or overhaul.

Electrical Equipment

116 The location of electrical equipment, including switchboard, is to be such that an accumulation of gas in the vicinity of such equipment is not possible.

MAIN BOILERS

Requirements for Burning Methane Gas

- 117 The boilers are to be equipped for oil firing in addition to the gas firing. Oil fuel alone is to be used for starting-up, manœuvring, and, except under clearly prescribed special conditions, for port operations.
- 118 Each boiler is to have a separate uptake to the top of the funnel or a separate funnel. The boiler room is to be separated from the engine room by a bulkhead, roller fire screen or equivalent. Special consideration will be given to proposals for combined engine and boiler rooms provided adequate ventilation arrangements ensure that any leakage of methane gas is extracted to atmosphere and other safety precautions are provided as required for each specific proposal.
- 119 The draught arrangements are to be such that a pressure differential is maintained between the boiler room and the combustion chamber either by induced

draught fans or by a closed stokehold system of forced draught. Alternatively, the boilers may be enclosed in a pressurised air casing.

- 120 The gas manifolds together with control valves are to be contained in a casing which is maintained below engine room pressure by an exhaust fan discharging to a safe position. Alternatively, the gas manifolds, valves, etc., may be contained in casings pressurised by inert gas as described in 112.
- 121 The firing equipment is to be of combined gas and oil type and be capable of burning both fuels simultaneously. The gas nozzles are to be so disposed as to obtain ignition from the oil flame which is to be present under all conditions of firing. A mechanical inter-locking device is to be provided to prevent the gas supply being opened until the oil and air controls are in the firing position. Each burner supply pipe is to be fitted with a gas shut-off cock and a flame arrester unless the latter is incorporated in the burner. An audible alarm is to be provided giving warning of loss of minimum effective pressure in the oil fuel discharge line or failure of the fuel pump.
- 122 Arrangements are to be made so that the gas supply to the gas manifold at each boiler can be shut off manually at the firing platform and will be shut off automatically as a result of failure of the forced draught fans or too low a pressure in the gas supply line.
- 123 In addition to the low water level fuel shut-off and alarm required by J 620 or J 635 for oil-fired boilers, similar arrangements are to be made for gas shut-off and alarm when the boilers are being gas-fired.
- 124 An inert gas or steam purging connection is to be provided on the burner side of the shut-off arrangements required by 122 so that the pipes to the gas nozzles can be purged immediately before and after methane gas is used for firing purposes.
- 125 A notice board is to be provided at the firing platform stating:—

If ignition is lost from both oil and gas burners, the combustion spaces are to be thoroughly purged of all combustible gases before re-lighting the oil burners,

MAIN OIL ENGINES

Requirements for Using Methane Gas

- 126 Main engines are to be of the dual fuel type employing pilot oil fuel ignition and capable of immediate change-over to oil fuel only. All starting and manœuvring is to be carried out on oil fuel alone.
- 127 The gas is to be admitted to each cylinder via a separate gas inlet valve; i.e. a system whereby gas is supplied to and mixed with air in a common inlet manifold is not acceptable from safety considerations. The gas supply pipes to individual cylinders are to be fitted with shut-off valves, non-return valves and flame arresters.
- 128 Isolating valves are to be provided at the inlet to the gas supply manifold for the engine and are to be arranged to close automatically in the event of low gas pressure and failure of pilot fuel injection. Arrangements are to be made so that the gas supply to the engine can be shut off manually from the starting platform.
- 129 Explosion relief valves are to be provided in the exhaust, scavenge and air inlet manifolds for conditions where, for example, a cylinder misfires due to failure of the pilot fuel injection or other derangement.
- 130 A cowl or casing connected to an exhaust ventilator is to be fitted over the cylinder tops so that gas leakages may be intercepted and led to a safe position. No electrical equipment is to be fitted inside these cowls and casings.
- 131 If a trunk piston engine is used the crankcase is to be fitted with smoke detecting equipment and means for the automatic injection of inert gas to avoid the special hazard of an explosion in a crank case which normally will contain a methane/air mixture. Crank case relief valves are also to be fitted as required by H 6.

Survey

132 The gas compressors, heaters, pressure vessels and piping are to be constructed under Special Survey, and the installation of the whole plant on board the ship is to be carried out under the supervision of the Society's Surveyors.

23rd July, 1970

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R (B)-PROVISIONAL RULES FOR PLASTIC PIPES

Section 1

101 Proposals to use plastic type materials in shipboard piping systems will be considered in relation to the properties of the materials, the operating conditions of temperature and pressure, and the intended service.

The Rules which follow are intended for extruded plastic pipes; they may also be used, where applicable, for fabricated plastic pipes glass reinforced. Any proposed service for plastic pipes not mentioned in these Rules is to be submitted for special consideration.

- 102 A specification of the plastic material giving mechanical and thermal properties is to be submitted for consideration.
- 103 In general, plastic pipes are not to be used where they will be subjected to temperatures above 49°C (120°F) or below 0°C (32°F).
- 104 Plastic pipes of approved type may be used for the following services:—
 - (a) Air and sounding pipes to tanks used exclusively for carrying water ballast or fresh water, with the exception of the portion above deck.
 - (b) Sounding pipes to cargo holds.
 - (c) Water ballast and fresh water pipes situated inside tanks used exclusively for carrying water ballast or fresh water.
 - (d) Scupper pipes draining inboard provided they are not led within the boundaries of refrigerated chambers.

Items (a) and (b) are not applicable to passenger ships.

105 Plastic pipes may be used for domestic and similar services for which there are no Rule requirements, as follows:—

Domestic cold salt and fresh water systems.

Sanitary salt water systems.

Sanitary and domestic waste pipes wholly situated above the freeboard deck.

Water pipes associated with air conditioning plants.

106 Since plastic materials are generally heat sensitive and very susceptible to fire damage, plastic pipes will not be acceptable for services essential to safety, as follows:—

Fire extinguishing pipes.

Bilge pipes in cargo holds.

Bilge and ballast pipes in the machinery space.

Main and auxiliary water circulating pipes.

Feed and condensate pipes.

Pipes carrying oil or other flammable liquids.

- 107 If plastic pipes are arranged to pass through watertight or fire-resisting bulkheads or decks provision is to be made for maintaining the integrity of the bulkhead or deck in the event of pipe failure. Details of the arrangements are to be submitted for approval.
- 108 Pipes are to be of robust construction, and in general so designed that the wall stress will not exceed $\frac{1}{7}$ of the tensile strength of the material at the working temperature. Particulars of scantlings and joints are to be submitted for consideration.
- 109 All pipes are to be adequately but freely supported; suitable provision for expansion and contraction is to be made in each range of pipes to allow for large movements between plastic pipe and steel structure—the coefficient of thermal expansion for plastics being eight or more times that of steel.
- 110 All fittings and branches are to be suitable for the intended service having joints of cemented, flanged, or other approved type.
- 111 The strength of the plastic material is to be check tested at the Surveyor's discretion. The tensile strength is to be determined by pressure tests to destruction on sample pipes. The pressure is to be so applied that failure of the pipe occurs in not less than five minutes. Bulging of the pipe during test is acceptable. The tensile strength is to be taken as the hoop stress at failure based on the original pipe dimensions.

28th February, 1963

ROW-PROVINGIAL BUILDS FOR PLANING PURS

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R (C)-PROVISIONAL RULES FOR THE CLASSIFICATION OF NUCLEAR SHIPS

Section 1

GENERAL

101 The class notation "Nuclear Powered" will be assigned, in accordance with the provisions of Chapter B, to sea-going ships equipped with a nuclear reactor or reactors for main propulsion and built in accordance with, or equivalent to, the relevant Rules and the following special requirements.

102 The requirements of Chapters C to Q apply as may be relevant to nuclear-powered ships, except as otherwise required by the following Rules.

HULL

Definitions

103 The containment structure is the vessel or ship compartment containing the reactor, primary circuit and associated equipment.

104 The containment protection length is the overall length of the containment structure plus a marginal length at each end. The marginal length is to be not less than B/5 with a minimum of 3 m (10 ft).

105 The reactor compartment is that compartment of the ship containing the containment structure. Where the containment structure is integral with the hull the reactor compartment is the containment structure (see 103).

Method of Construction

106 Welded construction is to be adopted for all structural material bounding the containment structure.

Quality of Material

107 The material of deck, sheerstrake, side and bottom shell plating, including keel, over the containment protection length is to be of Grade E.

Longitudinal Strength

108 Curves of weight and buoyancy in still water, and the corresponding bending moments and shear forces are to be submitted. The minimum section modulus for the hull shall be in accordance with the requirements of the Rules. In general, the arrangements and loading should be so adjusted that the maximum stress in still water does not exceed 90 per cent of the normal Rule maximum.

109 The longitudinal extent of the midship thicknesses of the deck, sheerstrake, side and bottom shell plating will be considered in association with the bending moment and shear force diagrams, but is to be not less than required by the appropriate section of the relevant Rules.

110 Continuity of longitudinal strength members is to be provided and rapid changes of section are to be avoided. The containment protection may be tapered to the normal structure over the marginal length.

111 Rigid shielding must not encase hull structural members unless built up in units with overlapping or socketed joints to permit free deflection of the ship girder. Thick steel or sandwich structures should not be made an integral part of the hull structure for similar reasons.

External Shock

112 The support system for the reactor and associated components should be designed to withstand a shock or impact acceleration of 3 g in any direction without general deformation of the structure.

Collision and Grounding Protection

113 No part of the containment is to extend outside a vertical datum B/5 metres (feet) inboard of the ship's side at the load water line.

114 The structure of the ship below the reactor and at the sides in way of the containment protection length will require to be specially considered from the aspect of absorption of the energy of collision and grounding forces.

115 Details of the side shell framing and collision protection structure in way of the containment protection length are to be submitted for approval.

116 A double bottom structure of depth not less than 1,85 m (6 ft) is to be fitted in way of the reactor and should incorporate a system of longitudinal framing in association with bottom transverses.

117 The integration of the containment with the hull structure should be such that the bottom shell in way of

the reactor should be capable of sustaining comparatively severe local damage without prejudicing the support of the reactor and its relative position in the ship.

118 A watertight longitudinal bulkhead is to be fitted between the reactor and the ship's side, not less than 1,5 m (5 ft) from the inner line of primary shell supporting members (or inner skin if double skin construction is adopted) at the load water line. The minimum clearance between this bulkhead and the reactor installation will be considered in association with the form of collision protection adopted. This bulkhead should, wherever possible, be in line with similar longitudinal material in the half length amidships. Where this is not possible, the arrangements for continuity are to be specially approved.

119 Proposals for the carriage of liquids, or siting of auxiliary machinery, abreast the reactor installation will be the subject of special approval.

Cargo Hazard Protection

120 Cargo spaces are to be isolated from the reactor compartment by a cofferdam not less than 1,5 m (5 ft) in length. For this purpose the machinery spaces and pump rooms will be regarded as equivalent to cofferdams. The modulus of the stiffening members of the cofferdam bulkhead adjacent to the reactor compartment is to be twice that required by D 50.

Containment Structure

121 Where containment is provided by a pressure vessel independent of the ship's structure, R (C) 216 to 225 apply.

122 The arrangements of such a containment structure are to be such that the transmission of stresses from the hull structure is reduced to a minimum.

123 Where the maximum major accident pressure (see R (C) 501) does not exceed 2 kg/cm² (30 lb/in²) gauge the containment may be provided by a compartment of the hull structure. All material of such containment structures is to have impact properties as specified for Grade E. Details of the proposed material are to be submitted.

124 The design stress for hull containment structures must not exceed two thirds of the yield stress or one third of the ultimate stress under the major accident conditions (see R (C) 501). Temperature effects will be specially considered. The structure should also be capable of withstanding an external pressure of 3,5 kg/cm² (50 lb/in²) gauge.

125 Containment structures are to be tested on completion in accordance with R (C) 224 and R (C) 225.

Section 2

PRESSURE VESSELS AND COMPONENTS

201 Pressure vessels and components for nuclear installations are to be considered in the following categories:—

Category "A"

Pressure vessels and components which are:-

 Intended to contain radioactive materials in service.

and

 Either (i) subject to direct neutron irradiation such that the physical properties of the materials of construction will be significantly affected during the projected life of the nuclear installation, or (ii) inaccessible for normal comprehensive periodic examination and maintenance from biological considerations of radioactivity.

Category "B"

Pressure vessels and components which are:-

 Intended to contain radioactive materials in service,

and

2. May be subject to direct neutron irradiation but not such that the physical properties of the materials of construction will be significantly affected during the projected life of the nuclear installation, but which will be accessible for normal comprehensive examination and maintenance at any selected time during the projected life of the nuclear installation.

Category "C"

Pressure vessels and components which are:-

- Not intended to contain radioactive materials in service.
- 2. May be subject to direct neutron irradiation but not such that the physical properties of the materials of construction will be significantly affected during the projected life of the nuclear installation and which will be accessible for normal comprehensive examination and maintenance at any selected time during the projected life of the nuclear installation.

Containment

Containment structures are defined in R (C) 103.

Category "A"

202 The materials of construction of these vessels are to be of a readily weldable quality, of adequate corrosion resistance and chosen from types which have been proven in pressure vessel service under similar conditions for non-nuclear applications. Data relating to the probable behaviour of materials under irradiation should be available.

203 Irradiation monitoring specimens representative of the materials of construction and of the welding of the vessels are to be provided. A programme of monitor specimen testing is to be drawn up covering the projected life of the nuclear installation.

204 Pressure vessels are to be designed and constructed generally in accordance with the Rules for Welded Pressure Vessels, Class 1. Alternatively, they may be designed generally in accordance with B.S. 1500 Class 1 or an approved code of a recognised National Authority.

The design conditions to be adopted are as follows:-

Design pressure is to be the maximum pressure under normal continuous and transient operation. Additionally, the relief valves must ensure that under emergency conditions the accumulation pressure must not exceed 1,10×design pressure.

Design temperature to be the maximum coolant temperature under normal operating conditions.

- 205 The effect of the following factors on stress levels must also be taken into consideration:—
 - (a) (i) Internal and external loading applied by or through circuits, supports and other connections, and self weight.
 - (ii) Temperature differentials and gradients occurring during normal operation, including start-up and shut-down.
 - (b) Shock and impact loading (see R (C) 112 and R (C) 521).
- 206 Special attention is to be given to effecting a clean design minimising stress concentrations. Reinforcement of major nozzle and other openings in the main pressure shell by the use of doubling plates is not permitted. Weldments are to be designed to permit 100 per cent radiography wherever possible.
- 207 The weld procedure specification is to be prepared giving details of the proposed methods of fabrication, including all pertinent welding variables and proposed methods of non-destructive examination. The specification must also include proposals in respect of the following:—
 - (a) Weld procedure tests to prove the proposed methods.

- (b) Welding operator tests to prove each welder's ability.
- (c) Production tests to prove the maintenance during fabrication of the standard of welding established and approved under weld procedure tests. Such tests are to be representative of the final conditions of the welding of the completed vessels and components.

The above tests are to be carried out under the conditions obtaining during fabrication.

208 On completion of fabrication, a hydraulic test is to be applied to a pressure 50 per cent in excess of the design pressure corrected for any increase in thickness incorporated as a corrosion allowance and for any difference in the physical properties of the vessel materials between test and design temperatures.

Category "B"

209 The requirements for vessels in this category are as for Category "A", except that irradiation data on materials is not required.

Internal and external access for normal comprehensive periodic examination of all vessels and components which are accessible from biological considerations of radioactivity is to be provided.

210 The pressure tightness of fuel assembly containers and associated coolant systems should also be considered in this category. Where closure of the pressure shell is effected by mechanical means, facilities are to be provided to test the integrity of the joint against leakage at any selected time.

Categories "A" and "B"

- 211 Vessels and components of the primary circuit are to be shop fabricated and shop tested wherever possible. The number of in situ closing welds must be kept to a minimum and adequate access is to be provided in each case.
- 212 On completion of the installation of the primary circuit a test pressure of 1,5 × design pressure is to be applied.

A leak test is also to be applied to the completed primary circuit for each proposed installation in a manner approved by the Society.

- 213 Provisions are to be made to facilitate periodic pressure and leak testing of the primary circuit.
- 214 Construction of these vessels is to be carried out in such a way that the high standard of cleanliness required can be attained.

Category "C"

215 Vessels in this category are to be designed, constructed and tested in accordance with the Rules for Welded Pressure Vessels (Chapter J) or other approved code or specification.

Containment

- 216 Materials for the construction of these structures are to be of a readily weldable quality and chosen from types which have been proven in service.
- 217 Where part of the ship structure is used as containment, R (C) 123 to 125 are applicable.
- 218 Pressure vessels are to be designed and constructed generally in accordance with the Rules for Welded Pressure Vessels, Class 1. Alternatively, they may be designed in accordance with B.S. 1500 Class 1 or an approved code of a recognized International Authority. The allowable design stress must not exceed the lesser of the following:—

Two thirds of yield stress (or two thirds of the 0,2 per cent proof stress),

One third of ultimate tensile stress.

219 No means of internal pressure relief are to be fitted.

The design conditions to be adopted are as follows:—

Design pressure (internal) is normally to be the major accident pressure in kg/cm² (lb/in²) gauge. (see R (C) 501).

Collapse pressure (external) is to be not less than 3,5 kg/cm² (50 lb/in²). Arrangements to protect the vessel when subjected to pressure in excess of the collapse pressure should be submitted for approval.

Temperature effects are to be considered (see R (C) 502).

- 220 The following factors are also to be taken into consideration:—
 - (a) Internal and external loading applied from ship's motion, machinery installation and shielding.
 - (b) Shock and impact loading (see R (C) 112 and R (C) 521).
- 221 Where it is envisaged that items of equipment within the containment will be removed or replaced during the life of the installation, adequate shipping openings with mechanical closures are to be provided to avoid recourse to cutting the containment structure in service.
- 222 The number and size of all openings in the pressure shell is to be kept to a minimum.

Isolating valves must be provided for all pipe circuits penetrating the pressure shell and these are to be situated in accessible locations outside, and adjacent to it. These valves are to be power operated or otherwise arranged to ensure rapid closure when containment is invoked.

- 223 A weld procedure specification is to be provided.
- 224 On completion of fabrication an internal hydraulic test to a pressure of at least 25 per cent in excess of the design pressure is to be applied.
- 225 A leak test to enable the determination of leakage rates from the containment structure at design pressure is to be conducted. Leakage from the containment structure should be kept to a practical minimum. The target figure to be adopted is 1 per cent in 24 hours of the free volume of the gaseous content in the containment vessel with all machinery installed.

Pressure Control and Over-pressure Relief

- 226 For each pressure vessel in the primary and secondary circuits in which it is possible under any fore-seeable conditions for the pressure to rise above the maximum design pressure, over-pressure relief must be possible.
- 227 The design requirements for primary and secondary pressure control systems are to include an agreed failure of the primary/secondary boundary. The effect of the consequent transfer of fluid from the primary to the secondary circuit or from the secondary to the primary circuit is to be assessed.

Discharge from primary pressure circuits is to be contained (see R (C) 513).

228 In systems where it is practicable to provide total relief capacity during any emergency condition by fitting one safety valve only, an additional safety valve of equivalent capacity is to be fitted. In multi-valve systems, additional safety valves are to be fitted in excess of the number required to provide total relief capacity. The number of additional valves to be provided will depend on the operational reliability of the safety valve types and the number involved.

Relief systems are to be designed to provide total relief capacity during any emergency condition with the maximum pressure accumulation of 10 per cent of the design pressure with the additional safety valves isolated.

229 Provision is to be made to detect leakage from each safety valve in normal operation. Provision is to be made to effect isolation of each safety valve during reactor and circuit operation. The shut-off arrangements are to be interlocked to ensure that the number of valves required to effect total relief are on line.

230 A pressure connection is to be provided to enable testing of safety valve lift in situ.

If block valves are proposed in safety valve discharge lines, a low pressure bursting disc must be incorporated in the valve design.

231 Proposed departures from the above requirements will be given special consideration.

Section 3

REACTOR ENGINEERING

General Requirements

- 301 Normal reactor and main machinery control during power operation are to be effected from a central control position external to the reactor compartment. An emergency reactor shut-down position with monitoring instrumentation is to be provided remote from the central control position.
- 302 Where isolation of the primary flow between reactor and heat exchanger is not provided, means of individual remote isolation of the secondary side of the heat exchangers is to be provided adjacent to the heat exchangers.
- 303 Individual isolation of the primary coolant subsidiary circuits is to be provided.
- 304 Data on the expected degree of irradiation effect to moderator and coolant is to be provided and the proposed method of monitoring and controlling such effect throughout ship life is to be stated.
- 305 Materials of construction which come into contact with primary fluid should be examined in relation to the build up of corrosion products activity within the reactor system. Details of proposed coolant treatment facilities are to be supplied.
- 306 Data and, if possible, experimental evidence relating to the power stability of the reactor under regular cyclic motions up to accelerations of 0,45 g as may be obtained in a seaway are to be provided. As a design criterion a period of 12 seconds should be used regardless of size and type of ship or position of reactor.
- 307 Special consideration is to be given to the fire resistance of all materials used in the containment structure and reactor compartment having regard to normal operating conditions and defuelling. Fire protection facilities provided in the containment structure and the reactor compartment are to be submitted for approval.

- 308 The provision and location of all spare equipment for nuclear components is to be detailed.
- 309 At least two independent means of charging coolant into the primary system are to be provided.

Reactor Core

- 310 A specification of all materials proposed for use in the core structure is to be submitted for approval.
- 311 The data and calculations utilised in the core design are to be submitted for approval.

Where necessary, adequate safeguards must be provided to prevent any dangerous chemical reaction between reactor materials and air or water.

- 312 The mechanical design, dimensional integrity and manufacturing tolerances of the core structure are to be submitted for examination and approval. Where applicable, the possible relative movement between neutron absorber control material and the core is to be assessed.
- 313 All possible normal and abnormal reactor transients are to be evaluated and their effect upon the dimensional stability and strength of the reactor core support structure is to be assessed.
- 314 It is recommended that all reactor pressure vessel internals are to be capable of being dismantled and removed from the pressure vessel. Proposals are to be submitted for consideration.
- 315 The core structure and fuel assembly are to be capable of withstanding shock and impact loading (see R (C) 112 and R (C) 521).
- 316 The expected change of the physical and chemical properties of the materials proposed for use in the fuel assembly, with irradiation, are to be submitted for approval.
- 317 The design of the fuel assembly and the operating criteria upon which the design is based are to be submitted for examination. All possible transient conditions (see 313) must be examined and related to possible fuel element failure. Experimental evidence of the mechanical strength of the fuel assembly resulting from transient conditions should be provided where possible.
- 318 The concentration and composition of fission products in the fuel at the end of the designed core life are to be assessed assuming a final period of 100 hours full-power operation.
- 319 The evidence upon which the fuel element dimensional stability has been assessed including, where possible,

previous reactor experience with the proposed fuel assembly up to the full proposed design irradiation is to be submitted for examination.

- 320 The consequences of salt water contamination of the primary coolant and the corrosion rates of the fuel assembly materials in coolant and in sea water are to be determined.
- 321 An analysis of the consequences of complete loss of coolant flow with and without control action is to be provided.
- 322 An analysis of the consequences of staggered loss of coolant flow with and without control action is to be provided.
- 323 An analysis of possible events leading to and resulting from the sudden introduction of cold coolant into the reactor core is to be provided.
- 324 The influence of random variations in moderator composition is to be examined.
- 325 An analysis of the consequences of a restriction of coolant flow in a fuel assembly is to be provided.
- 326 Each main coolant circuit must be provided with an independent means of circulating coolant. A single loop reactor system must be provided with a minimum of two main coolant circulators. It is recommended that a spare pump unit be carried.
- 327 Alternatively, if natural convection is proposed as a sole means for primary coolant circulation, proposals are to be submitted for consideration.
- 328 An analysis of the consequences of leakage of primary coolant and associated loss of pressure with and without control action is to be provided.

Decay Heat Removal

- 329 The arrangements to remove decay heat from the core under normal shut-down conditions are to be submitted for approval. Data, together with method of calculation, is to be provided showing the assessment of variation of decay heat with time.
- 330 Where a single loop circuit is proposed, a decay heat removal system independent of the main coolant loop is to be provided.
- 331 Facilities, independent of normal electrical power supplies, are to be provided to remove decay heat from the core at angles of list up to 50°.

It should be assumed that the ship lists to 20° instantaneously and that the list continues to increase at the rate of 20° per hour.

Section 4

REACTOR CONTROL

General Requirements

- 401 The proposed procedures for start-up and normal and emergency plant operation are to be submitted for approval.
- 402 The design of the control arrangements and any associated mechanism and the power supply to such mechanisms are to be submitted for approval. Evidence of operational reliability and proposed cycling tests to prove reliability are to be indicated.
- 403 The physical and chemical properties of materials used in control rod and associated mechanisms are to be submitted for approval. Corrosion rates of control equipment in reactor environment and in sea water are to be determined.
- 404 The control arrangements are not to move out of the core under gravity, under the force of coolant flow, shock loads or ship movement.
- 405 A degree of operator adjustment of the control arrangements is to be possible. Protection against possible operator error is to be provided.
- 406 The normal full-power operating temperatures of control rods are to be determined and the maximum temperature obtaining with one rod stuck in the core is to be determined, together with consequential effects.
- 407 The maximum insertion and withdrawal rate of any form of control is to be stated and related to possible reactor instability.
- 408 The consequences of continuous control rod withdrawal at start-up and full power are to be calculated.
- 409 The control equipment and its associated mechanisms when supported in their environment are to be capable of withstanding shock and impact loading (see R (C) 112 and R (C) 521).
- 410 The control arrangements are to be capable of operation at all ship angles and in the event of power failure must fail safe.
- 411 A margin of control should be completely withdrawn prior to criticality. The reduction of reactivity effected due to insertion of this margin at full power, at start-up and at all stages of core lifetime should be stated.
- 412 An alternative method of shutting down the reactor which is not affected by structural distortion of the core is to be provided, e.g., dumping of the moderator or change in moderator mixture or added poison. The time required to operate the system is to be stated.

Calculations or experiments supporting the design of the chosen system should be submitted for appraisal.

- 413 The plant parameters and the analysis of transient conditions under which emergency shut-down will be initiated are to be submitted for appraisal.
- 414 Emergency shut-down of the reactor must be implemented at the following ship conditions:—
 - (i) 50° list.
 - (ii) Flooding of the containment.
- 415 The method proposed to pressurise the primary circuit is to be submitted for approval.

Instrumentation

- 416 Control instrumentation and supplies are to be defined so as to meet control requirements and fault conditions. The instrument response to reactor transients is to be demonstrated.
- 417 All nuclear instrumentation, including health physics monitoring equipment, is to be described and its accuracy, reliability and range of operation demonstrated.
- 418 The method and extent of duplication of essential nuclear instrumentation and supplies is to be stated.

It is required that failure of any item of equipment in any channel shall result in a non-safe indication from that channel. Provision to test each channel without loss of reactor protection is to be possible.

- 419 All instrumentation relating to the reactor and the reactor compartment is to be described and the range of operation demonstrated.
- 420 Basic reactor safety instrumentation at the central control position and at the emergency shut-down position must be adequately shock mounted to ensure accuracy and reliability (see R (C) 112 and R (C) 521).

Section 5

COMPLEMENTARY INSTALLATION REQUIREMENTS

Major Accident

501 A containment vessel or structure is required that encloses all primary coolant circuits and the design of this is to be related to a pressure resulting from a major

accident. This accident should be based on an appreciation of the particular reactor design and is to include:—

- (a) Examination of possible nuclear transients contributing to the energy content of the primary circuit.
- (b) Assumption of complete severance of a main coolant pipe or equivalent failure occurring at working pressure and resulting in discharge of primary coolant into the containment.
- (c) Assumption that failure of the secondary circuit discharges a proportion of the secondary fluid into the containment.
- (d) Consequent exothermic chemical reaction which might result from core melt-down.
- 502 A pressure/time curve and temperature/time curve of the containment vessel contents covering the first 24 hours after the accident are to be submitted for examination, together with relevant calculations. In addition, the provision to prevent molten fuel penetrating the containment is to be indicated. Where "vapour suppression" or other such means of attenuation of the pressure rise following an accident are proposed full details are to be submitted at an early stage in the design, together with evidence of their effectiveness.
- 503 An assessment is to be made of possible damage to the containment structure by missiles produced as a consequence of a component failure inside the containment.
- 504 A summary of credible accidents covering each particular installation and indicating the degree of hazard involved is to be submitted for consideration. This summary must include a schedule of containment penetrations detailing methods of closure.

Shielding

- 505 Radiation contours in and around the hull, together with method of determination, are to be submitted for approval. Such contours should be determined for full-power operation, shut-down, dry docking, defuelling and after the major accident which invokes the use of containment.
- 506 In general, designers should work to the recommendations of the International Commission of Radiological Protection so that crews do not receive an integrated radiation dose in excess of 5 rem per year. When the integrated dose is calculated the possible need for maintenance work in high irradiation areas must be considered and it is recommended that 40 per cent of the total dose be reserved for this purpose.

507 The design of primary and secondary shielding, together with their siting and method of securing in the hull structure, are to be submitted for approval. Where necessary, arrangements for shield cooling and ventilation are to be indicated. Adequate periodic examination of the parent structure must be possible.

Defuelling and Refuelling

- 508 The arrangements for reactor shut-down for maintenance purposes and immediately prior to defuelling are to be submitted for approval.
- 509 Removal of a fuel assembly from the core into a container is to take place in such a manner that there will be no hazardous release of fission products to environment. The reactor core is to be in a containment of agreed design at all times. In addition, irradiation hazards to personnel are to be limited and should not exceed the maximum dose rates as recommended by the International Commission of Radiological Protection.
- 510 The fuel container is to be capable of being cooled and the consequences of failure of cooling are to be examined. The method of cooling and any related design of coolant circuit are to be submitted for approval.
- 511 The design of fuel containers is to be related to an approved maximum pressure and temperature to which they may be subjected, and the leak rate of the containers under such conditions is not to exceed 0,1 per cent per 24 hours of the gaseous volume of the container loaded with a fuel assembly.

Effluent Disposal

- 512 The facilities provided on board for the storage of radioactive material obtained from the reactor systems and the method proposed for the removal and the subsequent storage ashore is to be submitted for approval.
- 513 In general, containment of all solid and liquid effluents is required and the design of equipment used to effect such containment for a period of three months full-power operation and to permit its controlled discharge is to be submitted for approval.

Temporary storage and controlled discharge of innocuous concentrations of gaseous effluent is acceptable, subject to meeting national and international requirements.

Adequate monitoring devices for solid, liquid and gaseous effluent must be provided in all instances.

514 The designs and proposed method of operation of air circulating, air conditioning or air purging equipment in the containment structure are to be submitted for approval. The capacity of the equipment is to be related to the net volumes of the compartment and is to permit complete processing of such volumes in 30 minutes. All air before discharge is to be passed through a fission product clean-up unit.

Electrical Installations

- 515 Electrical installations are to be in accordance with Chapter M and, in addition, with the following Rules.
- 516 Limits of voltage and/or frequency between which equipment will operate satisfactorily are to be stated.
- 517 The electrical installation is to be such that failure of any component (e.g., generators, motors, busbars, protective devices or cables) does not interrupt the supply to services essential for the safety of the ship.
- 518 Emergency supplies in the event of reactor shutdown and/or failure of main supplies must be stated.

Secondary Circuit

519 Secondary circuit equipment and machinery, other than primary and secondary heat exchangers, are to conform with the Society's Rule requirements. Power must be available to permit normal manœuvring of the ship and the flexibility of the system is to be shown to accommodate all variations in main engine demand.

The reactor transients under such conditions are to be submitted for examination.

Emergency Power

520 Unless two or more reactors capable of independent operation are fitted, an independent power supply separate from and independent of the nuclear machinery must be available. The power output of such machinery must maintain a ship's speed of not less than six knots.

A range of 1600 kilometres (1000 miles) is recommended.

Shock

521 All reactor components are to be capable of withstanding an impact or shock acceleration of 3 g acting for a perceptible period of time in any direction using the yield stress or proof stress of the materials as a strength criterion.

Cleanliness

522 A high standard of cleanliness is to be maintained during construction of reactor components and their assembly into a hull. The methods and techniques required to obtain such a standard are to be submitted for approval.

Section 6

SURVEY AND MAINTENANCE

- 601 All proposed procedures for servicing and maintenance are to be included in the Operations Manual which is to be submitted for examination.
- 602 Hull and main machinery shall be subject to normal survey requirements.
- 603 All machinery used directly in conjunction with the reactor shall normally be subject to survey at fouryearly intervals, or at each refuelling period, whichever is the shorter.
- 604 The survey requirements for Category "A" pressure vessels and components will be given special consideration for each installation proposed.
- 605 The main steam generators and associated components in the containment which fall in Categories "B" and "C" (see R (C) 201), together with supports and seatings, shall be subject to survey at four-yearly intervals or at each refuelling period, whichever is the shorter.
- 606 Containment structures and supports are to be subject to survey at four-yearly intervals and a leak test is to be carried out at that time or in the event of minor modification or repairs to the pressure envelope. The leak test is to be carried out at 50 per cent of the major accident

pressure, or at a lower agreed figure provided a leak rate/ pressure curve has been determined.

- 607 An air test to the design pressure is to be carried out on a containment structure whenever a major modification or repair to the pressure envelope is made, or when significant deterioration of the envelope is noted.
- 608 Double bottom structure external to and in way of the containment vessel shall be subject to survey at four-yearly intervals or at each refuelling period, whichever is the shorter.
- 609 Primary and secondary shielding, together with associated parent structure, shall be subject to survey at four-yearly intervals or at each refuelling period, whichever is the shorter.
- 610 The design of the reactor installation should permit maintenance work, servicing and inspection to be carried out without excessive exposure of personnel to radiation hazards, which should not exceed permissible dose rates as laid down by the International Commission of Radiological Protection.
- 611 Containers for radioactive material are to be subject to examination by the Society's Surveyors at two-yearly intervals except that, where chemical decontamination is used or other severe conditions obtain, it may be required that more frequent examinations be effected.

29th April, 1965

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R (D)-GUIDANCE NOTES ON METAL PIPES FOR WATER SERVICES

Section 1

PIPES FOR SEA WATER SERVICES

Types of Corrosion

101 The following types of accelerated corrosion have arisen with piping materials for sea water services:—

- (a) Galvanic corrosion of the less noble metal where dissimilar metals were in association.
- (b) Pitting corrosion, the main causes being local attack by deposits or transfer of small pieces of metal such as weld spatter, sulphides in polluted esturine waters, gassing in hot tubes of coolers, fouling and cathodic films in the bores of pipes as a result of incorrect methods of manufacture or fabrication.
- (c) Corrosion-erosion where water speeds are excessive for particular metals. This may be particularly severe where turbulence occurs, e.g., protrusions in pipe bores, tight bends.
- (d) Dezincification of some types of brasses including "manganese bronze".
- (e) Stress corrosion cracking of copper-zinc alloys.
- (f) Severe local corrosion due to sulphur and/or sulphide contamination of pipes.
- (g) Cavitation erosion where water speeds are very high.
- (h) Rusting of steel pipes when no protection has been applied or where protection has proved insufficient due to manufacturing fault or damage.
- 102 Metals differ in their resistance to these various forms of corrosion but even where corrosion resistant types have been used, inadequate attention to design detail or workmanship has caused failures. The following are recommendations for the selection of materials and practices.

Materials for Pipes and Flanges

103 Steel pipes should be protected against corrosion. Galvanizing of the bores is the most common practice and is recommended as the minimum protection. All steel pipes of bilge and ballast lines should be galvanized.

Galvanized steel pipes should not be used for continuous service where water speeds exceed about 3 m/second (10 ft/second).

The life of a galvanized coating depends on its thickness which to some degree is controlled by pipe thickness. In some cases, it may be advisable to use a pipe of heavier gauge. Welds should be free from lack of fusion and crevices. Where possible, the surfaces should be dressed to remove slag and spatter and, where possible, this should be done before galvanizing. Preferably the coating should be continuous round the ends of the pipes and on the faces of flanges.

The lining is resistant to all forms of corrosion and is particularly effective against scouring by sand. A good bond between the rubber lining and the steel of the pipe is essential. Preferably the rubber lining should be carried round the ends of the pipe and over the faces of the flanges to act as jointing material. There should be no discontinuities or pinholes in the lining, through which corrosion can occur and lift the coating. For these reasons rubber linings should be applied by specialist firms and care taken to avoid damage to finished coatings.

The foregoing comments also apply to plastic-lined pipes. Pipes with stoved coatings are also efficient, but care should be taken to avoid mechanical damage to flanges.

Coatings of the above types should be applied on completion of fabrication, i.e., forming and welding of steel pipes.

105 Copper pipes are particularly susceptible to perforation by corrosion-erosion. These pipes have given the greatest trouble in sea water systems. In some cases copper pipes have been replaced by galvanized steel pipes which have given superior performance.

The cause of the failures of copper pipes has been due mainly to the continuation of an established practice over a period when water speeds have increased appreciably. Low water speeds should be used with copper pipes and excessive local turbulence should be avoided.

106 Certain copper alloys have enhanced resistance to impingement attack and can be used where water speeds are higher than can be tolerated by copper. These alloys are as follows:—

Copper—30 per cent Nickel—0.8 per cent Iron Alloy. Copper—10 per cent Nickel—2 per cent Iron Alloy.

Aluminium Brass.

Admiralty Brass.

Copper-5 per cent Nickel-Iron Alloy.

In general, aluminium brass pipes and tubes give reliable service with reasonably clean sea water. For service with polluted river or harbour waters copper-nickel-iron alloy pipes and tubes are preferable. The nickel content of the alloy for these conditions should not be less than 10 per cent. New copper alloy pipes should not be exposed initially to polluted water. Reasonably clean sea water should be used first in order that the metals can develop protective surface films.

107 Austenitic types of stainless steel are not recommended as they are prone to deterioration when in contact with polluted waters.

108 Where pipes are exposed to sea water on both external and internal surfaces, flanges should be made preferably of the same material. When sea water is confined to the bores of pipes the material of the flange is of less importance from the point of view of corrosion. However, flanges of the same or a less noble metal than that of the pipe, are recommended. Gunmetal flanges on aluminium brass pipes are an exception to this recommendation. Brass for flanges should be of the type containing 1,0 to 2,0 per cent tin to minimise dezincification.

109 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or capillary silver-brazed joints as appropriate. Where welding is used, the fillet weld at the back should be a strength weld and that in the face a seal weld.

Where silver-brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable.

A combination of a silver-brazed joint at the front face and a normal brazed joint at the back face has given satisfactory service when the bore surface only was exposed to sea water.

110 With copper-nickel-iron alloy pipes, flanges of a similar type of alloy or of mild steel may be attached by argon are welding. A mild steel flange should not be used when it will be in contact with sea water.

Copper, brass, bronze, gunmetal or copper-nickel-iron alloy flanges may be capillary silver-brazed to copper, aluminium brass or copper-nickel alloy pipes. "Bronze welding" should not be used. Brazing of inhibited alpha brass flanges to copper pipes using rods of a 92,75 per cent copper-7,25 per cent phosphorus alloy has given satisfactory service. The alloy used for silver-brazing should contain not less than 49 per cent silver.

Mild steel flanges should be fusion welded or flash butt welded to mild steel pipes. 111 Alpha brasses must be properly inhibited against dezincification by suitable additions to the composition. Alpha-Beta brasses or those containing less than 70 per cent copper should not be used for pipes and fittings.

Design Considerations

112 In sea water, galvanic corrosion may cause premature failure of a component when it is in contact with one of a more noble metal. For guidance, Table R(D) 1.1 gives the galvanic series for common metals in sea water. A metal in direct contact with one lower in the list may suffer accelerated corrosion in sea water.

TABLE R(D) 1.1

GALVANIC SERIES IN SEAWATER

Zinc
Aluminium
Carbon Steel
Cast Iron
Lead-Tin Solders
Lead
Brasses
Copper
Phosphor Bronze

Gunmetal Copper-Nickel-Iron Alloys

Aluminium Bronze

Monel Metal

Where components are made from different metals, preferential corrosion of the less noble metal may be minimized by the introduction of a sacrificial anode. This is made of a metal which is higher in the Table than either of the working metals. Where a sacrificial anode is used to provide local protection, there should be an efficient electrical bond between it and the metal which it is to protect.

- 113 Water speeds should be carefully assessed at the design stage and the materials of pipes, valves, etc., selected to suit the particular conditions.
- 114 Attention should be given to the design, fabrication and installation of systems to ensure streamlined flow. In particular, abrupt changes in the direction of flow, protrusions into bores of pipes and other restrictions of flow should be avoided.

Pipe bores should be smooth and clean. Any carbonaceous films or deposits formed on the bore surfaces of nonferrous pipes during bending processes should be carefully removed. Jointing should be flush with the bore surfaces of the pipes. Branches preferably should be set at a shallow angle to the line of the main piping, the junction should be smooth and the branch should not protrude into the bore of the main pipe. Tight bends should be avoided. The bore surfaces should be smooth at these positions and free from puckering.

- 115 Very low water speeds and stagnant zones should be avoided. Systems should not be left idle for long periods especially where the water may be polluted.
- 116 Strainers should be provided at the inlets to sea water systems.
- 117 Non-ferrous pipes which are fairly heavily cold worked during fabrication should be annealed or stress relief heat treated before they are put into service. Finished aluminium or Admiralty brass pipes, in particular, should not be overstrained to facilitate alignment and tight joints.

Section 2

PIPES FOR FRESH WATER SERVICES

201 The corrosive conditions in fresh water systems are less severe than in sea water systems and generally mild steel or copper pipes are satisfactory for service in fresh water applications.

21st May, 1964

- 202 Mild steel pipes should not be left idle for long periods if the water has a low salt content. This low salinity and the limited supply of oxygen promote the formation of black iron oxide on the bores of the pipes which gives rise to severe corrosion of the pipes. Where stagnant conditions are unavoidable steel pipes should be galvanized or pipes of suitable non-ferrous material should be used. Hot fresh water may promote corrosion of mild steel pipe unless the hardness and pH of the water are controlled.
- 203 Copper alloy pipes should be treated by scouring or other means to remove any harmful cathodic films from the bores before pipes and tubes are despatched from the makers' works.
- 204 Brass fittings and flanges in contact with water should be made of an alpha brass which is inhibited against dezincification.
- 205 Aluminium brass pipes and fittings are not recommended for fresh water services as, under certain circumstances (not yet completely defined), premature failure by pitting and/or cracking can occur.

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R (E)—GUIDANCE NOTES ON TORSIONAL VIBRATION CHARACTERISTICS OF MAIN AND AUXILIARY OIL ENGINES

Section 1

TORSIONAL VIBRATION CRITICAL SPEEDS AND LIMITING VIBRATION STRESSES

General

101 In oil engine installations torsional critical speeds occurring between idling and full speeds are generally inevitable and these guidance notes are intended to safeguard machinery from the effects of excessive torsional vibration during the life of the ship.

The stress limits recommended provide reasonable margins to avoid shaft fatigue failure. Critical speeds at which the stress limits would be exceeded, should be avoided for continuous operation.

Careful attention, however, should be given to the dynamic system at the design stage to ensure, in particular, that significant critical speeds requiring "barred" ranges are avoided within the speed range(s) proposed for continuous operation in service. See 104, "Barred" Speed Ranges.

The stress limits set out in the following paragraphs should not be viewed necessarily as design values, but rather as values which should not be exceeded where critical speeds of appreciable importance cannot reasonably be avoided.

The stresses considered in these notes are nominal values based on the plain section of the shafting, excluding stress raisers.

Between 90 and 100 per cent of the maximum continuous speed, the stress limits apply to the sum of the vibratory stress due to any resonant order and stresses due to the dynamically magnified portions only of the flanks of other significant orders (i.e., subtracting the stresses due to the exciting torques).

Where critical speeds are found by calculation to show stresses approaching the limits, torsiograph records may be required. In practice, differences between calculated stresses and stresses measured by torsiograph or equivalent are frequently found. Where such differences arise, the stress limits are to be applied to the measured stresses.

The stress limits are applicable to steel shafts having a tensile strength of 44 to 52 kg/mm² (28 to 33 ton/in²). For shafts of high tensile steel or other material, the stress limits will be subject to special consideration.

Where the scantlings of crank shafts, webs, couplings, coupling bolts and straight shafting are greater than required by the Rules, higher vibratory stress limits may be considered.

Engine Speed R.P.M.

102 Maximum continuous speed N_S may be defined as the maximum revolutions per minute for which the engines are classed in continuous operation.

In the case of constant speed generating sets for main propulsion or auxiliary purposes N_S is taken as the full load R.P.M.

Any special speed requirements for prolonged periods in service should be indicated, e.g., range of trawling R.P.M., range of operating R.P.M. with controllable pitch propeller, idling R.P.M., etc. Such speed ranges should be maintained clear of significant critical speeds so far as practicable.

Governor Control

103 For closely governed installations, the application of formulæ 110 (4) and 111 (4) may be restricted to revolutions 5 per cent higher than the governor control limit, with a minimum of 1,10 N_S, provided such limit be demonstrated during engine trials.

"Barred" Speed Ranges

104 Where restricted speed ranges are imposed as a condition of approval, a notice board is to be displayed at the control station(s) stating that continuous operation should be avoided between the limits indicated by formulæ 110 (2) and 111 (2), and the tachometers marked accordingly. In such cases the tachometer accuracy should be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ± 2 per cent in way of the restricted range of revolutions.

Where vibration stresses due to criticals below 0,8 N_S marginally exceed the limiting stress for continuous operation, or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

Where such vibration stresses approach the limiting values f_t given in formulæ 110 (3) and 111 (3) the range of revolutions restricted for continuous operation may be extended, and the notice board(s) should indicate that this range must be passed through rapidly.

In cases where the resonance curve of a critical speed has been derived from torsiograph measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured vibration stresses are in excess of the limiting stresses for continuous operation, having regard to the tachometer accuracy.

Excessive Vibration Stresses

105 In cases where vibration stresses exceed the limiting values, the dynamic system should be re-designed, or damping or detuning arrangements provided to remove the critical speed from the operating range or to reduce the magnitude of the vibration stress.

It is preferable to avoid the use of dampers or detuners to control criticals within the range between 0,85 and 1,05 N_S, but if fitted they should be of a type which makes adequate provision for dissipation of heat and contain no mechanical parts subject to deterioration in service.

Where dampers or flexible couplings are fitted, it may be required that torsiograph records be taken to verify their efficacy.

Gear Hammer

106 In installations having reversing and/or reduction gearing, or geared scavenge blowers, etc., where the vibratory torques at the gears exceed the mean transmission torques at the criticals considered, it may be necessary to impose a restricted range of revolutions in way of each critical speed at which gear hammer occurs.

Further, in the event of gear hammer being detected at speeds other than the calculated critical speeds, torsiograph records may be required to confirm the calculated natural frequencies.

In all cases where there is a possibility of gear hammer, the backlash in the gears should be kept to a minimum.

At critical speeds near the maximum speed the vibratory torque should not, in general, exceed one-third of the full transmission torque. In cases where the proposed loading on the gear teeth is less than the maximum allowable special consideration will be given to the acceptance of additional vibratory loading on the gears.

Screw Shafts

107 The stress limits for screw shafts apply to fully protected shafts having a continuous liner with efficient sealing arrangements against corrosion of the shaft by sea water, and to shafts without liner which are oil lubricated and which are fitted with an approved type of oil gland.

In other cases special consideration will be necessary. The limits are intended to apply to the minimum

section of the shaft between the forward end of the propeller boss and the forward stern gland.

Intermediate Shafts

108 The stress limits for intermediate shafts apply to shafts having integral flanges with Rule fillet radii.

Where loose couplings are employed, the vibration stresses in the shaft in way of the coupling should be limited to 75 per cent of these values.

Definition of Symbols

109 In the formulæ for determining vibration stresses, the symbols used are as follows:—

N = engine speed R.P.M.,

N_S = maximum continuous engine speed R.P.M. (see 102),

 $N_c = critical speed R.P.M.,$

r = ratio N/N_S or N_C/N_S whichever is applicable,

d = minimum shaft diameter considered, in mm (in),

 $f_C = maximum$ value of the vibration stress for continuous running at or below maximum speed, in kg/cm^2 (lb/in²),

$$\begin{split} f_t &= \text{maximum value of vibration stress due to} \\ &\quad \text{criticals below 0,8 N}_S \text{ necessitating restricted} \\ &\quad \text{ranges, in kg/cm}^2 \text{ (lb/in}^2\text{),} \end{split}$$

f = maximum value of the vibration stress above maximum speed, in kg/cm² (lb/in²).

Propelling Machinery-Vibration Stress Limits

Crank and Screw Shafts

110 Where the critical occurs at or below the maximum R.P.M., vibration stresses not exceeding values given by the following formula are considered satisfactory for continuous running:—

$$f_C = \pm (315 - 0.22d) (1.6 - r^2)$$
 (1)

$$(f_C = \pm (4500 - 80d) (1 \cdot 6 - r^2)$$
 British)

Where the vibration stresses exceed the limiting values for continuous running as given by formula (1), a notice board should be fitted at control stations stating that the engine should not be run continuously between the following speed limits, above and below the critical speed, and the engine tachometers should be marked correspondingly:—

Range of engine R.P.M. to be avoided:-

From
$$\frac{16 \text{ N}_{\text{C}}}{(18-r)}$$
 to $\frac{(18-r) \text{ N}_{\text{C}}}{16}$ inclusive (2)

The maximum values of the vibration stresses due to such criticals should not exceed those given by the following formula:—

$$f_t = 2 f_c$$
 (3)

Criticals should be arranged sufficiently removed from the maximum R.P.M. to ensure that, in general, at r=0.8 the stress due to the upper flank does not exceed f_C (formula (1)).

Where the critical occurs above the maximum R.P.M., the vibration stresses should not increase beyond values given by the following formula at revolutions up to 1,16 times the maximum R.P.M.:—

Intermediate and Thrust Shafts

111 Where the critical occurs at or below the maximum R.P.M., vibration stresses not exceeding the values given by the following formula are considered satisfactory for continuous running:—

$$f_{C} = \pm (535 - 0.22d) (1.44 - r^{2})$$

$$(f_{C} = \pm (7600 - 80d) (1.44 - r^{2}) \text{ British})$$
(1)

Where vibration stresses exceed the limiting values for continuous running as given by formula (1), a notice board should be fitted at control stations stating that the engine is not to be run continuously between the following speed limits, above and below the critical speed, and the engine tachometers should be marked correspondingly:—

Range of engine R.P.M. to be avoided:-

From
$$\frac{16 \text{ N}_{\text{C}}}{(18-r)}$$
 to $\frac{(18-r) \text{ N}_{\text{C}}}{16}$ inclusive (2)

The maximum values of the vibration stresses due to such criticals should not exceed those given by the following formula:—

$$f_t = 1.7 f_C \tag{3}$$

Criticals should be arranged sufficiently removed from the maximum R.P.M. to ensure that, in general, at r=0.8 the stress due to the upper flank does not exceed f_C (formula (1)).

Where the critical occurs above the maximum R.P.M., the vibration stresses should not increase beyond values given by the following formula at revolutions up to 1,16 times the maximum R.P.M.:—

$$f = \pm (235-0,097d) (1+5\sqrt{r-1})$$

$$(f = \pm (3340-35d) (1+5\sqrt{r-1})$$
 British)

Auxiliary Machinery and Propulsion Oil Engine Driven Generators

112 The following notes are applicable to oil engines developing 150 bhp or 100 kW and over, driving auxiliary machinery used for essential services and to propulsion oil engine driven generating sets operating at constant speed.

The dynamic system comprising engine and driven machinery should be so designed that vibration stresses in the crank shafts and transmission shafting resulting from critical speeds do not exceed values given by the following formula within speed limits of 0,95 and 1,10 N_S, N_S being the full load R.P.M.:—

$$f_{c} = \pm (212-0.14d)$$
 (1)
 $(f_{c} = \pm (3000-50d) \text{ British})$

Vibration stresses in the crank shaft and transmission shafting due to critical speeds which have to be passed through in starting and stopping should not exceed values given by the following formula:—

$$f_t = 5.5f_C \tag{2}$$

Furthermore, the amplitudes of vibratory inertia torque imposed on generator rotors should be limited to \pm 2,0 $Q_{\rm S}$ over the speed range from 0,95 to 1,10 $N_{\rm S}$ and to \pm 6,0 $Q_{\rm S}$ in passing through criticals below 0,95 $N_{\rm S}$, where $Q_{\rm S}$ is the rated full load mean torque.

The rotor shaft and structure should be designed to withstand the foregoing magnitudes of vibratory torque.

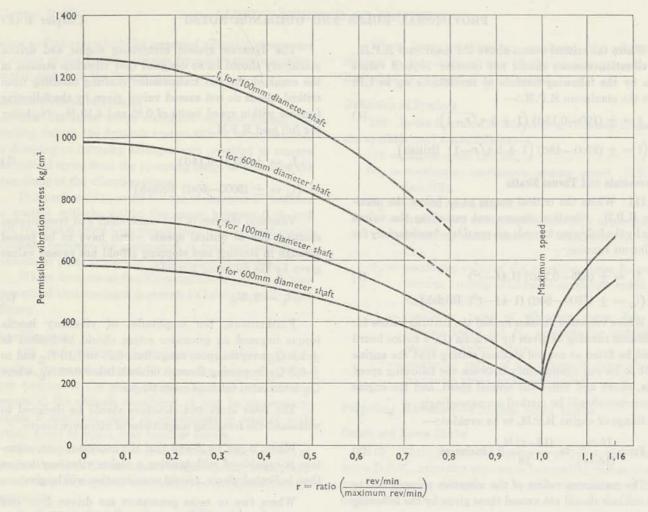
Where it can be shown that the generator rotor structure is capable of withstanding a higher vibratory torque than indicated above, special consideration will be given.

Where two or more generators are driven from one engine, each generator should be considered separately in relation to its own designed rated torque.

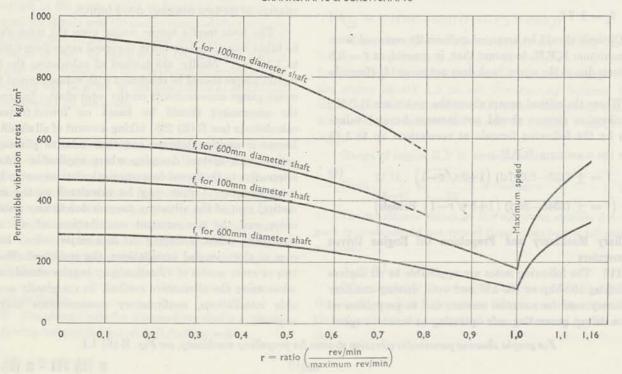
The total inertia torque acting upon the rotor should be taken into consideration in the speed range from 0,95 NS to 1,10 Ns. Ideally, the method of calculating the total inertia torque should be consistent with values derived from strain gauge measurements on the rotor shaft. In general, the assessment should be based on forced-frequency calculations (see R (E) 225) taking account of all significant harmonic exciting torques and their relative phases, together with system damping where applicable. As an alternative to the forced-frequency calculations method, the total vibratory torque may be calculated as the arithmetical sum of the vibratory torques due to any resonant order and the non-resonant contributions of all other significant orders, including the first major order. In the case of close-coupled installations, the combined effect of two or more modes of vibration may require consideration when using the alternative method. In marginally acceptable installations, confirmatory measurements may be required.

LLOYD'S REGISTER OF SHIPPING

INTERMEDIATE & THRUST SHAFTS



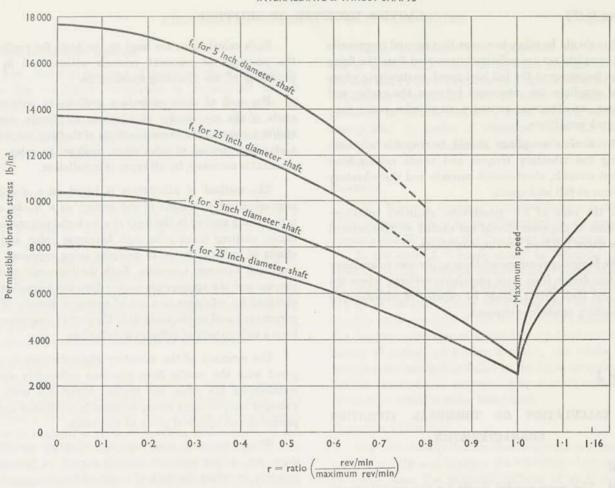
CRANKSHAFTS & SCREWSHAFTS



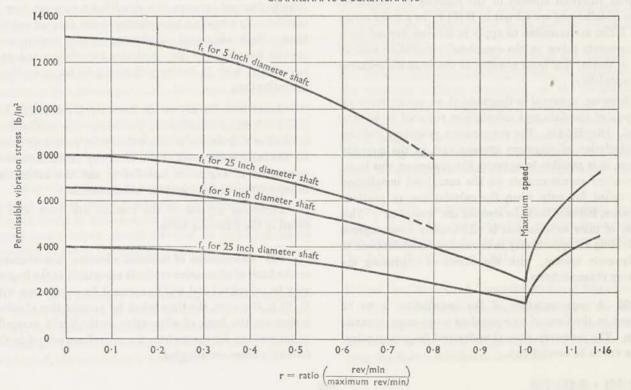
Permissible Vibration Stresses for Propelling Machinery.

Fig. R (E) 1.1 (Metric)

INTERMEDIATE & THRUST SHAFTS



CRANKSHAFTS & SCREWSHAFTS



Permissible Vibration Stresses for Propelling Machinery.

Fig. R (E) 1.1 (British)

Care should be taken to ensure that natural frequencies of the complete set are sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator, as otherwise excessive amplitudes could arise under such conditions.

The flexible couplings should be capable of withstanding the vibratory torques and twists arising from transient criticals, short-circuit currents and the vibratory conditions at full load speed.

In the case of a.c. generators, resultant vibratory amplitudes at the rotor should not exceed \pm 2,5 electrical degrees under full load working conditions.

The foregoing recommendations apply also to auxiliary generators driven from main propulsion systems, where the rotors and their drives should be capable of withstanding the vibratory conditions imposed.

Section 2

THE CALCULATION OF TORSIONAL VIBRATION CHARACTERISTICS

General

201 The recommended limits for the magnitudes of torsional vibration stresses in the shafting of marine oil engine installations are set out in R (E) 1. In a strict sense, these limits are intended to apply to stresses derived from measurements taken on the completed installation and, in cases of doubt, this basis remains as the ultimate criterion of acceptability.

However, approval is desirable at an earlier stage on the basis of the data and calculations required to be submitted. (See H 242). The examination procedure includes the calculation of vibratory stresses and, in the majority of cases, it is possible to approve the system on this basis, confirmatory measurements on the completed installation being called for only when the calculations, or previous experience, indicate that the stresses are "marginal". This process of prior examination is additionally advantageous in providing an opportunity to recommend modifications to the dynamic system, with the object of improving the vibratory characteristics.

202 A representation of the installation is to be prepared in the form of an equivalent multi-mass dynamic system. The necessary natural undamped frequency calculations are to be carried out.

Such calculations are used as the basis for predicting the positions of resonant criticals within, and in the proximity of, the operating speed range.

For each of these criticals a preliminary estimate is made of the magnitudes of vibratory amplitude, stresses and/or torques in the various sections of shafting, employing a standard method of calculation, designed to cater, with reasonable accuracy, for all types of installation.

The method of calculation is based on a simplified semi-empirical treatment of the system as a whole, excitation being applied in the form of a vectorial summation of engine exciting torques for each harmonic order, and the effects of various sources of damping being expressed as a combined dynamic magnifier. Both the harmonic exciting torques and the appropriate engine dynamic magnifiers are obtained by reference to a set of averaged curves. These curves are based on the analysis in the past of measurements from a wide variety of different installations.

The estimate of the vibratory characteristics is compared with the results from previous sufficiently similar installations (to allow for typical departures from the average) and, in most cases, acceptable conditions can be predicted and approval given at this stage.

Where, however, more complex vibratory conditions arise, e.g., where resonant criticals cannot be treated in isolation, or where the flank of a critical has an appreciable effect at the maximum continuous engine speed, or in heavily damped systems, the simplified treatment may be insufficiently revealing, necessitating more detailed calculations. Such additional calculations usually require more specific knowledge of the particular installation and vary too widely, both in nature and scope, to be amenable to generalisation.

Apart from its use as the basis for the Society's torsional vibration examination procedure, the standardized method of calculation is also valuable in providing means for the early assessment of the vibratory characteristics of new types of engine or installation and the subsequent interpretation of torsiographic measurements.

Particular aspects of the method are dealt with in detail in the following notes.

203 Calculations of torsional vibration characteristics on the basis of alternative methods acceptable to the Society may be submitted and will be assessed for compliance with R (E) 1. However, the time taken for examination of calculations on the basis of alternative methods will normally be longer than for cases where the procedures set out in the following notes are adopted.

Equivalent Dynamic Systems

204 For the purposes of torsional vibration calculations the machinery installation is represented by an equivalent dynamic system consisting of a number of discrete rigid inertias separated by massless shafts. The equivalent shafts are expressed in terms of torsional stiffness, although the reciprocal form is an acceptable alternative.

REFERRED SYSTEMS

205 In the case of geared installations, comprising shafts rotating at different speeds, the equivalent dynamic system is referred to the speed of the engine crank shaft, for ease in later calculation. For multi-engined installations, although the basic principles of the method are equally applicable, special considerations associated with the possible variations in the mode of operation and indeterminate phasing of engines, will require some modification to the standard procedure and mode of presentation.

CRANK SHAFT SYSTEMS

206 The engine system is divided into a number of inertias, each concentrated at the cylinder centreline. The effective inertia per cylinder line is taken as the average value throughout a cycle of rotation and consists of the inertia of all the rotating elements, including balance weights and a portion of the connecting rod, together with the inertia given by one-half of the mass of the reciprocating elements considered concentrated at the crank pin radius. In the case of a "Vee" engine, the inertias for each pair of cylinders are combined into a single inertia.

Accurate estimation of the equivalent shaft stiffness between engine cylinder centres is complicated by the irregular shape of the crank shaft. Numerous formulæ for evaluating the stiffness per crank throw have been published and their applicability varies as between different engine types. Enginebuilders are advised to check the validity of their estimates for new crank shaft designs, either by static stiffness tests or indirectly by natural frequency measurements for the crank shaft mode of vibration.

(A similar difficulty in assessing shaft stiffnesses occurs in some types of driven machinery, particularly in the case of rotor shafts in close-coupled generator installations, and experimental means should likewise be employed where necessary to verify the estimated values).

PROPELLERS

207 It is necessary in estimating the effective inertia of marine propellers to make an allowance for entrained water. In the absence of detailed information, this allowance is taken as 25 per cent. Where a value other than 25 per cent is adopted, the amount is to be stated.

Where controllable pitch propellers are fitted, two sets of calculations, based on dynamic systems having 25 per cent and 10 per cent entrained propeller water allowance respectively are carried out, in order to estimate the difference in natural frequency when working at full and zero pitch. In modes of vibration where the effect of entrained water is negligible, one set of calculations will suffice.

DAMPERS

208 Where a torsional vibration damper is fitted to the machinery, this is to be represented in the equivalent dynamic system used in the frequency calculations.

In the case of "viscous shear" or "slipping torque" types of damper, where the seismic mass is not mechanically connected to the rest of the system, the damper is represented by an effective inertia comprising the casing or hub, together with one-half of the inertia of the seismic mass. For dampers consisting of a seismic mass flexibly driven by means of springs or rubber elements, the whole of the seismic mass inertia is included in the dynamic system. The flexible connection is represented by a shaft stiffness, the dynamic or effective value being used.

FLEXIBLE COUPLINGS

209 Torsionally flexible shaft couplings are frequently used to modify and improve the vibratory characteristics. In many cases the torsional stiffness of such couplings varies as between static and dynamic conditions of loading, and, wherever possible, the effective dynamic stiffness as determined by experiment is to be used in compiling the dynamic system.

Certain types of flexible couplings are designed with non-linear or discontinuous torque/deflection characteristics, the torsional stiffness depending on the magnitude of transmitted torque and/or speed of rotation. In such cases, depending on the relative importance and position in the speed range of the significant critical speeds, it may be necessary to calculate natural frequencies on the basis of a range of coupling stiffnesses in the equivalent dynamic system.

210 The particulars of the equivalent dynamic system should be summarized in tabular form, together with other relevant data for use in subsequent calculations. See Tables R (E) 2.1a and 2.1b.

Natural Frequencies and Associated Modes of Vibration

211 The natural torsional frequencies of the installation together with their associated modal characteristics are calculated on the basis of the equivalent dynamic system, using the Holzer tabulation technique.

The number of modes requiring to be investigated varies as between different installations, but the search should be carried out up to a frequency equivalent to 15 times the maximum continuous speed of the engine. This ensures that it will be possible in later calculations to account for critical resonant conditions arising from all harmonic torque excitations up to order 12, in a speed range extending up to 125 per cent of the maximum continuous engine speed.

212 The information obtained from the natural frequency calculations for each mode of vibration should be summarized as in Table R (E) 2.2.

The relative amplitude in Col. 2 of the Table is arranged to have a value of unity at the mass position corresponding to engine cylinder No. 1 (i.e., the cylinder farthest removed from the driven machinery). Consequently the vibratory torques listed in Cols. 3 and 4 and the shaft stresses in Col. 6 relate to a modal amplitude of 1 radian at engine cylinder No. 1. From these values of relative amplitude, phase-vector sums are calculated and tabulated for all relevant modes. (Table R (E) 2.3). In addition, the stress factors listed in Col. 6 are corrected for the actual shaft speed, the reduction gear ratio, where applicable, having been taken into account.

The Prediction of Vibratory Magnitudes by Calculation

213 Each torsional mode of vibration having a natural frequency, F, cycles/min, is excited by the harmonic components of the applied torque, the order number of each harmonic being denoted by m. Resonant conditions associated with these harmonic orders of excitation arise at a series of critical running speeds, given in general by

$$N_c = F/m$$
 R.P.M.

214 The magnitudes of vibration are to be estimated for all such critical conditions occurring in a speed range extending from 10 per cent up to 125 per cent of the maximum continuous engine speed, N_S.

For each critical speed, N_c , considered, the amplitude of torsional vibration, θ_1 , at engine cylinder No. 1 is given by

$$\theta_1 = \pm M \theta_0$$
 radians,

in which,

M = dynamic magnifier for the whole system, (See 217 to 222),

$$\theta_{0} = \frac{\mathsf{T}_{\mathsf{m}} \; \mathsf{A} \; \mathsf{R} \; \overline{\Sigma} \, \dot{\Delta}}{\omega^{2} \; \Sigma \; (\mathsf{J} \; \Delta^{2})} \quad \mathrm{radians,}$$

T_m = resultant mth order harmonic component of tangential effort at each crankpin, expressed per unit area of piston, in kg/cm² (lb/in²), (See 216),

A = area of each piston, in cm² (in²),

R = crank radius, or mean crank radius for opposed piston engines, in cm (in),

 $\Sigma \dot{\Delta}$ = phase-vector sum for all engine cylinders, (Table R (E) 2.3), derived from the frequency table relative amplitudes and the M^{th} order phase angle diagram.

 ω = natural phase velocity of the mode of vibration, in rad/sec,

 Σ (J Δ^2) = summation of terms, obtained from the natural frequency table (Table R (E) 2.2), for the whole system, in kg cm sec² (lb in sec²).

215 Having calculated the vibratory amplitude, θ_1 , the corresponding stress in any shaft in the system is obtained by multiplying θ_1 by the appropriate stress factor in Col. 6 of the tabulated natural frequency data. (Table R (E) 2.2).

By a similar process of scaling, magnitudes of vibratory amplitude and torque, where these quantities are of interest, are predicted for any part of the system, making use of the entries in the appropriate columns of the Table.

Thus, for example, in geared installations, predictions relating to the likelihood of vibratory torque reversal, and hence "gear-hammer", arising at resonant conditions are based on a comparison between the estimated vibratory torque occurring at the gear mesh and the mean driving torque transmitted at the particular running speed. In this connection, the inertia of the gearing is split into driving and driven components in the natural frequency calculations, thereby permitting a better assessment of the vibratory torque at the actual gear mesh.

As a further example, in the case of generator installations, a comparison is required between the vibratory inertia torque imposed on the armature and the full load mean torque. Here the inertia torque is obtained from the appropriate entry in Col. 3 of the tabulated data (Table R (E) 2.2).

Harmonic Torque Components

216 Figs. R (E) 2.1a and 2.1b give averaged curves of resultant components of tangential effort (T_m) per unit area of piston, plotted against cylinder mean indicated pressures, for each harmonic order, m.

Although presented in a form suitable for 4-stroke engines, the curves for the integral order harmonics apply equally to 2-stroke engines (including opposed piston engines), the appropriate values being doubled.

Inertia torque components, due to the reciprocating parts, have not been taken into account in these curves and the values used for the first three integral order harmonics require suitable correction in individual cases.

In certain installations it may be necessary to consider excitation from the propeller as well as from the engine.

Dynamic Magnifiers

217 Although the method already described for calculating magnitudes of vibration at critical speeds involves the use of a dynamic magnifier applying to the system as a whole, the more important sources of damping are determined individually. The partial dynamic magnifiers so obtained are then combined on an empirical basis to give an overall magnifier for the complete system. (See also 222).

ENGINE MAGNIFIER

218 The dynamic magnifier associated with the effects of damping arising within the engine, M_E , is expressed as a function of θ_O ,

$$M_E = 3.8 \ \theta_0^{-\frac{1}{4}}$$

For convenience, this expression is given in graphical form in Fig. R (E) 2.2.

In practice, the value of M_E , so obtained, is limited to a maximum of 50.

In installations where the engine provides the only appreciable source of damping, or in modes of vibration insensitive to damping arising elsewhere, the engine magnifier, M_{E} , becomes the effective magnifier, M, for the whole system.

PROPELLER MAGNIFIER

219 Propeller damping, which assumes importance in the case of shafting modes of vibration of propulsion machinery, is taken into account by the use of a propeller dynamic magnifier, Mp, determined from the following formula:—

$$M_{p} = \frac{\sum (J \Delta^{2}) N_{s}^{3} m}{680 000 a H \Delta^{2}_{p}}$$

$$\left(M_{p} = \frac{\sum (J \Delta^{2}) N_{s}^{3} m}{600 000 a H \Delta^{2}_{p}}\right) \text{ (British)}$$

in which

 Σ (J Δ^2) = summation of terms for the whole system, in kg cm sec², (lb in sec²),

N_s = maximum continuous engine speed, R.P.M.,

m = harmonic order number,

H = rated brake horsepower at the maximum continuous engine speed, metric (British),

 $\Delta_{\rm p}=$ relative modal amplitude at the propeller, radians, (referred to crank shaft speed in the case of a geared installation),

a = coefficient, taken as 30 (average value),

$$= \frac{\mathsf{K}_{\mathsf{p}}\,\mathsf{N}_{\mathsf{c}}}{\mathsf{Q}_{\mathsf{c}}}$$

where

 $K_{\rm p}={
m propeller\ damping\ coefficient},$ in kg cm sec/rad (lb in sec/rad),

Q_C = mean propeller torque at critical speed, in kg cm (lb in),

N_C = propeller speed at critical, R.P.M.

Where the propeller design is such as to indicate that its damping properties may be other than the average assumed in the above formula and also in the case of a controllable pitch propeller, an appropriate adjustment to the coefficient, a, may be accepted, based on the geometrical parameters of the propeller, or on the evidence of measured results.

VIBRATION DAMPER MAGNIFIERS

220 Vibration dampers in general vary widely in their mode of operation. Assessment of the damping properties of a particular combination of damper and engine system, together with the corresponding equivalent damper magnifier, M_D, should be carried out in consultation with the damper manufacturers and the predictions verified by practical measurement on a typical installation. (See R (E) 105).

In the particular case of a viscous-shear type of damper, the additional damping influence (assumed to be under optimum conditions of tuning) is calculated by taking a dynamic magnifier

$$\mathsf{M}_{\mathsf{D}} = \frac{2,0\;\Sigma\;(\mathsf{J}\;\Delta^2)}{\mathsf{J}_{\mathsf{R}}\;\Delta_{\mathsf{D}}^{\;2}}$$

where

 Σ (J Δ^2) = summation for complete system, including contribution from the effective damper inertia,

J_R = moment of inertia of the seismic mass,

and Δ_D = relative modal amplitude at damper casing.

FLEXIBLE COUPLINGS

221 Many types of flexible couplings, apart from providing convenient means for modifying and improving the natural frequency characteristics of machinery installations, also are designed to have a controlling influence on the systems under resonant conditions, either by the incorporation of true damping principles or by virtue of detuning effects produced by non-linear torque/deflection relationships. This ability to reduce the magnitude of resonant criticals is usually confined to modes of vibration having appreciable relative angular deflections across the coupling elements. The manufacturers should be consulted regarding the appropriate characteristics of the coupling with reference to energy loss/cycle, and for novel types the value assumed is to be confirmed by measurement on a typical installation.

COMBINED DYNAMIC MAGNIFIER

222 The overall dynamic magnifier, M, for the system as a whole is obtained by combining the magnifiers, estimated for the individual sources of damping, in the following empirical manner:—

$$M = \left[\left(\frac{1}{M_E} \right)^2 + \left(\frac{1}{M_P} \right)^2 + \left(\frac{1}{M_D} \right)^2 + \dots \right]^{-\frac{1}{2}}$$

Non-Resonant Conditions

223 The procedure outlined in the previous Sections is intended to provide means for predicting magnitudes of vibration at resonant criticals in the operating speed range.

In many cases, however, levels of vibration, sufficiently high to warrant further consideration, may occur under non-resonant conditions away from critical speeds.

This situation frequently arises near the maximum continuous engine speed where the machinery may be operating on the flank of a particularly powerful critical, or where the cumulative effect of a complex of resonant criticals and flank conditions, attributable to several orders of harmonic excitation, may have to be taken into account.

224 The normal procedure for estimating the magnitude of vibration on the flank of a single critical is to calculate first the amplitude, $\theta_{\rm O}$ at resonance (as in 214). The amplitude $\theta_{\rm F}$ for the flank condition (corresponding to $\theta_{\rm I}$), is then obtained from the following formula:—

$$\theta_{\text{F}} = \pm \; \theta_{\text{O}} \left[\left\{ 1 \, - \left(\frac{N}{N_{\text{O}}} \right)^2 \right\}^2 + \left(\frac{N}{N_{\text{O}}} \right)^2 \frac{1}{M^2} \right]^{-\frac{1}{2}} \label{eq:theta_F}$$

where

N = engine speed at the required flank condition,

N_c = critical speed,

M = dynamic magnifier at resonance.

The required magnitudes of flank amplitude, torque and stress in the system are deduced from the application of $\theta_{\rm F}$ as a scaling factor to the tabulated natural frequency data (Table R (E) 2.2), on the assumption that the latter remain valid for the flank conditions as well as for resonance, which is normally sufficiently accurate. If the harmonic torque component at the engine speed considered differs appreciably from that at the critical speed, the former value is used as the basis for calculating $\theta_{\rm O}$.

225 The foregoing approach, in which a particular non-resonant operating condition is considered to be situated on the flank of an adjacent isolated critical may, in certain cases, be an over-simplification. This situation arises in systems having a number of natural frequencies fairly close to one another, such that a single harmonic order appreciably excites several modes of vibration, whose contributions to the total vibratory conditions cannot be ignored. In these circumstances the vibratory conditions are to be investigated by non-resonant forced frequency tabulation techniques, and where damping has an important influence, this is to be included in the calculation procedure.

15th January, 1970

TABLE R (E) 2.1a

PARTICULARS OF OIL ENGINE MACHINERY

Ship's Name:—
Description and Class:-
Shipbuilders:—
Enginebuilders:-

Description of Machinery:-

Yard No. Engine No.

Engine Data:-

Firing Order:-

Max. Press.:—
M.I.P.:—
Max. cont. engine BHP:—
Max. cont. engine RPM:—
Idling RPM:—

Balance Wts. disposition:—
inertia:—
Span of Bearings:—
Crankshaft Plan No.:—

Propeller and Shafting Data:-

Propeller Dia.:—
No. of Blades:—
Fixed Pitch/C.P.:-
Inertia (dry):-
Propeller Plan No.:—

No. of Screw Shafts:—
Max. cont. RPM:—
Working Range of RPM:—
Cont. Liner/Oil Gland:—
Shafting Layout Plan No.:—

Auxiliary Machinery Data:-

Generator Make and Type:—
Rating AC/DC, KVA/KW, full load/no load RPM:—
Whether Unit on Resilient Mountings:—

Rotor Shaft Plan No .:-

Gearing Data:-

Make and Type:— Speed Ratios:— Gearing Plan No .:-

Vibration Damper Data:-

Make and Type:—
Seismic Mass Inertia:—
Hub or Casing Inertia:—
Spring Stiffness, Static/Dynamic:—
Damping Coefficient:—

Flexible Coupling Data:-

Make and Type:—
Stiffness, Static/Dynamic:—
Max. Cont. Vibratory Torque:—
Coupling Damping:—

Additional Features

TABLE R (E) 2.1b

Equivalent Dynamic System:-

Mass Number	Description	Inertia J kg cm sec ² (lb in sec ²)	Shaft Stiffness C 10° kg cm/rad (10° lb in/rad) or I/C	Minimum Shaft Diameter d cm (in)	Shaft Speed reduction G	Engine Cylinder firing angles, degrees	
Number						А	В
							el .
			teall to				
		HOLES -	Lall .				
	Anni Halperson -	antiquette at II e	misti			Andrew Va	-ye-
		- yad pp dud	dant dan				
	(1) + (1)	- abott visit					in No.
Paul I			DWA D				orl y l
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			:180	Earl September		24.00 A 31	

NOTES:—TABLE R (E) 2.1b

The minimum sectional modulus of the shaft in torsion, Z, in cm³ (in³), is to be stated where the shaft is not of solid circular cross-section.

The speed reduction, G, in a geared system is related to the crank shaft speed, i.e., G = crank shaft speed/shaft speed.

The cylinder firing angles are to indicate the true angular position for each cylinder in the firing sequence whether 2- or 4-stroke cycle. For "Vee" engines the firing angles for both cylinders on one pin are required at each crank.

Columns A and B relate to the cylinder banks of a "Vee" engine. In the case of an "In-line" engine only one column is required.

TABLE R (E) 2.2

Frequency, F =	C.I	P.M.	No. of Nodes =		$\omega^2 =$
Col. 1.	Col. 2.	Col. 3.	Col. 4.	Col. 5.	Col. 6.
Mass Number	Relative Amplitude Δ (Radians)	Inertia Torque $J \omega^2 \Delta/10^6$ 10^6kg cm (10^6lb in)	Modal Shaft Torque $\Sigma \int \omega^2 \Delta / 10^6$ 10^6kg cm (10^6lb in)	J Δ ² kg cm sec ² (lb in sec ²)	Nominal Shafe Stress Factor $\frac{G}{Z} \sum \frac{J}{10^{\circ}} \frac{\omega^{2} \Delta}{10^{\circ}}$ $\frac{10^{\circ} \text{kg/cm}^{2}}{(10^{\circ} \text{lb/in}^{2})^{*}}$
			$\Sigma (J \Delta^2) =$		

 $\omega = \text{Natural phase velocity of the mode of vibration (rad/sec)},$

F = Natural frequency of vibration (cycles/min).

$$F = \frac{60 \, \omega}{2 \, \pi}$$

(For definition of other symbols see Table R (E) 2.1b)

* Per radian at No. 1 cylinder

TABLE R (E) 2.3

CRANK ARRANGEMENT



VECTOR SUMMATION

Orders	Resultant for 1 radian at No. 1 cylinder				
	1-node	2-node	3-node		

Mean indicated pressure (kg/cm²) Fig. R (E) 2.1a (Metric)

Fig. R (E) 2.1a

0 2

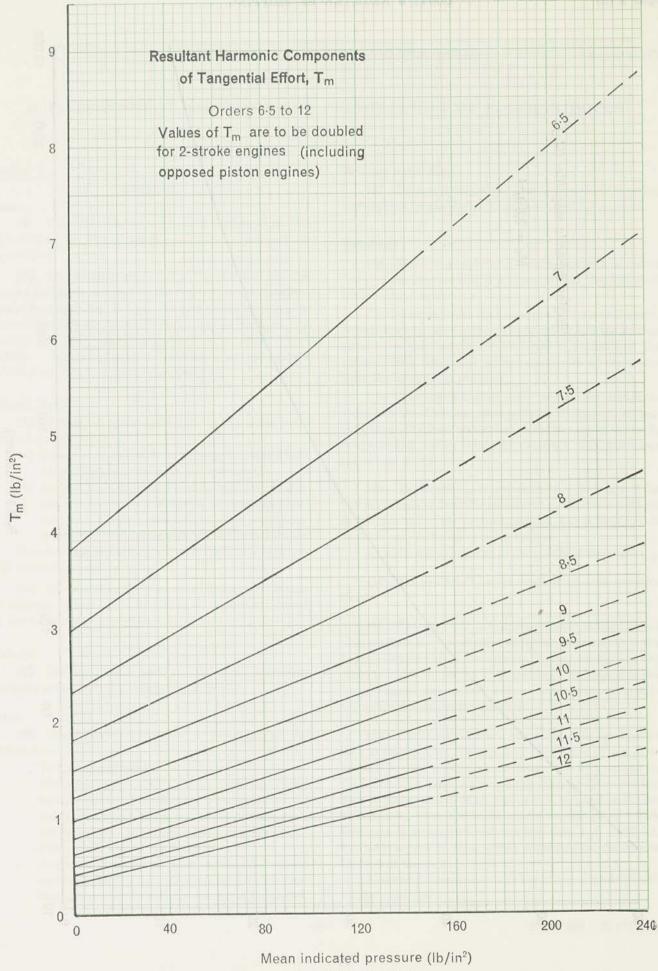
4

Fig. R (E) 2.1b (Metric)

661

Fig. R (E) 2.1a

662



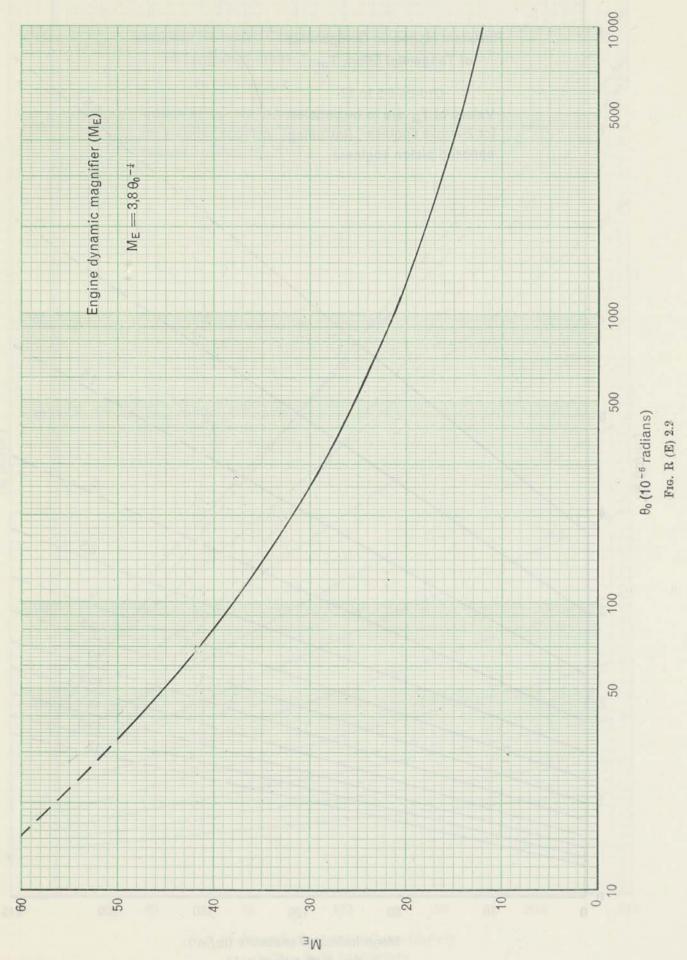


Fig. R (E) 2.2

R (F)-PROVISIONAL RULES FOR THE CLASSIFICATION OF FLOATING DOCKS

Section 1

GENERAL

Class

101 The class assigned to Floating Docks will be "A" "Floating Dock. For service at (port to be specified)".

102 The requirements of this Chapter indicate the general standards required by the Society for the classification of floating docks. In view, however, of the variations in operating conditions for which docks may be designed, the Society will give special consideration to other design criteria. Where considered necessary, an appropriate notation will be added to the class assigned.

General Design

103 The requirements apply directly to floating docks of the following types:—

(a) Caisson type, in which the bottom caisson and both wing walls are continuous and inseparable.

(b) Pontoon type, in which the wing walls are continuous and the bottom is formed of non-continuous pontoons. The pontoons may be either permanently attached to the wing walls or may be detachable.

The scantlings and arrangements of docks of other types will be specially considered.

104 The preceding Chapters of the Rules apply as may be relevant to floating docks except as otherwise required by the following.

Material

105 The mild steel used for the main structural members of the dock shall comply with D 104.

Plans

106 The following plans are to be submitted for approval:—

Section at mid-length.

Structural plan of wing walls, top deck, safety deck and, for pontoon type docks, the plating across the base of the wing walls in way of the pontoon gaps. Structural plan of bottom caisson or pontoons. Fresh water and oil fuel tanks.

A general arrangement plan, hydrostatic curves and the necessary data for calculating longitudinal strength (see R (F) 201) are also to be forwarded.

Working Instructions

107 On completion of the dock a copy of the Working Instructions for the dock is to be submitted for approval.

Definitions

108 The lifting capacity is the displacement in tonnes (tons) of the heaviest ship it is intended that the dock shall lift in normal service.

This lifting capacity shall be approved for classification, but the Society reserves the right to reduce it if the sinkage trials show that insufficient freeboard is available at the pontoon deck when this lifting capacity is added to the light displacement of the dock.

The light displacement shall include the structural weight of the dock complete with all machinery, cranes, equipment, full fresh water, fuel oil for the use of the dock, compensating ballast water (if required), and rest-water (as defined in 115).

109 The length L_D , in metres (feet), is the length of the bottom caisson or from the aft end of the aftermost pontoon to the fore end of the forward pontoon, but is exclusive of portable end platforms or swing bridges.

Amidships is to be taken as the middle of the length L_D.

110 The breadth B_D is the moulded breadth in metres (feet).

111 The depth D_D, in metres (feet), is the vertical distance from the lowest point of the bottom framing to the beam at outer wall of the uppermost deck (in 403 the top deck) to which the dock may theoretically be lowered in the water without sinking and without water penetrating into the compartments under this deck.

112 The safety deck is a watertight deck arranged at such a height below the top deck that when all compartments below the safety deck are flooded but with no load on the keel blocks, there is a reasonable freeboard from the top deck to the waterline. If air pipes are to be fitted under the safety deck, these are to be shown on the plans. This freeboard is generally to be not less than 1 m (3·25 ft), but may require to be amended depending on the service location of the dock.

Alternative arrangements to the fitting of a safety deck will be considered.

113 The freeboard to the pontoon deck at the centreline of the dock when supporting a ship whose displacement
is the lifting capacity (as defined in 108) shall be not less than
300 mm (12 in). When the pontoon deck at the inner
side walls is lower than at the centre, the freeboard to the
pontoon deck at the inner side walls shall be not less than
75 mm (3 in) and the freeboard at the centreline shall
be not less than 300 mm (12 in). These freeboards assume
the travelling cranes are positioned to give no trim; the
freeboard at level trim shall be such that when both cranes
are moved to the forward end or to the after end of the
dock, the pontoon deck shall not be submerged. These
freeboards shall depend also on the location of the dock.

114 The length L_S, in metres (feet), is the length between perpendiculars of the shortest ship whose displacement is equal to the lifting capacity of the dock (as defined in 108), the breadth and draught of the ship being the maximum the dock can accommodate, and the block coefficient assumed to be 0,80. The length so calculated may have to be adjusted to give realistic proportions and, in general, the breadth B assumed need not be taken as greater than that corresponding to the following proportions:—

Ls (metres)

60 80 100 120 140 160 180 200 220 240 260 280

Ls (feet)

190 260 330 400 460 520 580 640 710 780 850 920

Ls/B

5,7 6,2 6,7 7,2 7,2 7,2 7,2 7,2 6,8 6,4 6,0 5,6

- 115 The rest-water is the ballast water in the tanks which the pumps cannot discharge.
- 116 Compensating ballast water is ballast water which may be used to control the deflection of the dock under longitudinal bending. Rest-water is not included in compensating ballast water.

Section 2

LONGITUDINAL STRENGTH

General

201 The longitudinal strength is to be calculated for the condition when the ship of length $L_{\rm S}$ (described in R (F) 114) is supported on the keel blocks, the centre of the ship's length being over the mid-length of the dock, and the freeboard at the pontoon deck is as described in R (F) 113. The level of ballast water is to be constant over the length $L_{\rm D}$ (as defined in R (F) 109).

Ship Weight Curve

202 The weight curve of the ship is to be taken as a rectangle with a superimposed parabola of half the area of the rectangle, the length of each area being L_S.

Bending Moments

203 The conditions described in 201 and 202 will result in a sagging bending moment, the units being tonne m (ton ft).

Modulus of Section

204 The material to be included in the calculation of the section modulus will be, for the caisson type dock, all continuous fore and aft material of the whole dock (i.e., wing walls structure and bottom pontoon).

For the pontoon type dock all continuous fore and aft material of the wing walls structure may be included together with the fore and aft material of the parts of the pontoon which are directly under the wing walls structure (i.e., material of pontoon lying between the lines of the inner walls is not included in the modulus calculation for this type of dock). At the section in way of the gap between pontoons, all continuous fore and aft material of the wing walls structure may be included, together with the horizontal plate across the base of the outer and inner walls, provided this plate extends longitudinally at least 2 m (78 in) over each pontoon.

The modulus of section calculation is to be included with the longitudinal strength data (see R (F) 106). The modulus units are to be in cm³ (in² ft).

See also 207.

Permissible Stresses

- 205 When it is intended that the normal operation of the dock shall be with ballast water evenly distributed over its entire length, the stress in the bottom or deck, computed from the data in 203 and 204, is not to exceed 1400 kg/cm² (8·9 ton/in²).
- 206 When it is intended that the normal operation of the dock shall be by differential emptying of the ballast compartments, the stress with the ballast water suitably distributed shall be in accordance with 205.

In addition, the section modulus of the dock shall be not less than that required to ensure that the stress does not exceed 2200 kg/cm² (14 ton/in²) when the ballast water (of the amount used in the condition described in the preceding sub-paragraph) is evenly distributed over the length of the dock.

207 An approximate value of the section modulus required to give the permissible stress may be derived from the formula:—

$$Section\ modulus = \frac{12\,500\ L.C.}{f} \left(\text{CL}_{\text{D}}-0.917\ \text{L}_{\text{S}}\right) \text{cm}^3$$

$$\left(\frac{\text{L.C.}}{8\text{f}}\left(\text{CL}_{\text{D}}-0.917\text{L}_{\text{S}}\right)\text{in}^{2}\text{ ft}\right)$$

where L.C. = lifting capacity of the dock, in tonnes (tons),

L_D = length of dock (see R (F) 109), in metres (feet),

 $L_S = \text{length of ship (see R (F) 114), in metres (feet),}$

f = either 1400 kg/cm² or 2200 kg/cm² (8·9 ton/in² or 14 ton/in²) the permissible stress (see 205 and 206),

C = 1,0 for caisson type docks

and
$$c = a + \frac{nb}{n-1}$$
 for pontoon type docks,

where n = number of pontoons,

a = fraction of length of dock taken up by pontoons,

and b = fraction of length of dock taken up by gaps between pontoons.

208 Where the dock has to be towed in open waters from the port of construction to the port of operation, the total permissible stress en route is not to exceed 1730 kg/cm² (11 ton/in²). The designer's calculations of this stress are to be submitted. The wave conditions should assume a length of wave equal to L_D and height of wave the maximum expected to be encountered during the voyage in tow.

Extent of Scantlings

209 The scantlings of members included in the modulus calculation (see 204) shall be maintained over 20 per cent of the length of the dock L_D on each side of the longitudinal middle of the dock.

Deflection Meters

210 Two different types of deflection meter are to be fitted, the readings to be shown on an indicating board in the control rooms.

The meters shall be of the electrical and optical types and the deflections shall be obtained over the length of the dock L_D . The deflection corresponding to a stress of 1400 kg/cm² (8·9 ton/in²), when lifting the ship defined in R (F) 114, shall be stated in the Working Instructions. See R (F) 107.

Alternative means of recording deflection will be specially considered.

Section 3

TRANSVERSE STRENGTH

General

301 The transverse strength is to be calculated, for the condition described in R (F) 201, at the centre of the length of the dock and towards the ends of the dock using the ship weight curve described in R (F) 202, and the modulus so required (see 303) is to be applied throughout the length of the dock.

Bending Moment

302 The bending moments on the transverses of the bottom caisson or pontoons are to be evaluated for the above condition and positions in tonne m (ton ft) units.

Modulus of Section

303 The material to be included in the calculation of the section modulus of a transverse will be the continuous athwart dock material associated with the transverse. The effective width of pontoon deck and of pontoon bottom plating to be taken with the transverse is to be calculated from the information given in D 5304.

Permissible Stresses

304 The compressive and tensile stresses computed from 302 and 303 are not to exceed 1730 kg/cm² (11 ton/in²).

Section 4

LOCAL STRENGTH

General

401 Plating and supporting stiffeners designed to meet the requirements of R (F) 205, R (F) 206, R (F) 208 and R (F) 304 may require to be increased to satisfy local strength requirements. Alternative means of computing scantlings to meet these requirements may be used when a copy of such calculations is to be submitted.

Tank Plating and Stiffeners

402 The thickness of plating in ballast tanks, oil tanks, fresh water tanks and sewage tanks is to be obtained from D 1907 and the scantlings of the stiffeners in these tanks are to be obtained from Chapter D, Table 40 of the 1967 Rules. For ballast tanks the pressure head to be used in association with the above is to be that obtained from an analysis of the hydrostatic curves.

Top Deck Plating

403 The thickness of plating for the middle 40 per cent of the length is to be as required for longitudinal strength. For 10 per cent of the length L_D at each end of the dock the thickness may be 6,5 mm (0·25 in), (with an increase of 3 per cent for every 25 mm (1 in) that the spacing of longitudinals exceeds 610 mm (24 in)), unless local conditions require a greater thickness. For the intermediate lengths (each of 20 per cent of the dock length) the thickness of the deck will be given proportionate values.

Top Deck Longitudinals

404 It is assumed the top deck will be stiffened longitudinally for the middle 40 per cent of the length. The scantlings of longitudinals will generally be those required to obtain the area necessary for the section modulus derived from longitudinal strength considerations but shall be not less than specified below for longitudinals at the ends.

For 10 per cent of the length L_D at each end of the dock the scantlings of the longitudinals are to be such that the stress under a loading of 1465 kg/m² (300 lb/ft²) does not exceed 1100 kg/cm² (7 ton/in²). The loading may require to be increased to suit the general arrangement of a particular dock.

The scantlings of the longitudinals in the intermediate length are to be intermediate between those required for the middle and end portions.

Safety Deck Plating

405 The thickness of plating of this deck, with the exception of those areas covered by 402, shall be in accordance with D 1907 using a depth 70 per cent of the height between decks (top of safety deck beam to top of top deck beam at side). This assumes a stowage rate of 1,39 m³/tonne (50 ft³/ton); where the stowage rate exceeds this value the depth to be used is to be increased proportionately. When air pipes project into the ballast tanks (see R (F) 501), it may be that the head corresponding to the maximum pressure in the air cushion will exceed the above value of the depth; in this case the depth used will be that corresponding to the air cushion pressure.

Safety Deck Beams

406 The beams under the safety deck, with the exception of those areas which are covered by 402, shall be in accordance with Chapter D, Table 40, of the 1967 Rules, and associated notes; the head H is to be used in this context being the value of the depth obtained as described in 405.

Framing

407 Framing of side walls, bottom, and pontoon deck shall be in accordance with Chapter D, Table 40, of the 1967 Rules, and associated notes, the head H being obtained from an analysis of the hydrostatic curves.

Transverses and Web Frames

408 The loadings on the deck transverses are to be in accordance with 402, 404 or 406, whichever is applicable. The width of deck supported by the transverse shall be the width between the inner and outer side walls and the length shall be the spacing of transverses.

The loading on deep side frames and bottom transverses shall be obtained from an analysis of the hydrostatic curves.

The permissible stress in transverses and deep frames shall be 787,5 kg./cm.² (5 ton/in²).

Cross Ties

409 Cross ties when fitted between the inner and outer wing walls shall be in accordance with D 4901, the value of h being obtained from an analysis of the hydrostatic curves.

Watertight Bulkhead Plating and Stiffeners

410 Pontoon centreline girder, when watertight, and watertight side girders shall be in accordance with 402. The strength of these items must also be considered in conjunction with the requirements of 412.

Non-Watertight Bulkheads

411 Non-watertight girders in pontoon. The thickness of plating is to be 7,5 mm (0·30 in). The scantlings of stiffeners are to be determined from D 1414 to D 1418, the load P being based on the head of water obtained from an analysis of the hydrostatic curves, to which the pontoon deck and bottom plating is subjected.

The strength of these items must also be considered in conjunction with the requirements of 412.

Keel Blocks and Supporting Structure

412 The loading to be taken (over the whole length of the dock) by the keel blocks and supporting structure shall be $\frac{1,167}{L_S}$ × the lifting capacity, in tonne m (ton ft).

Platforms Extending from Ends of Dock

413 The loading on these structures is assumed to be 586 kg/m² (120 lb/ft²). If a heavier loading is anticipated or required, the plans are to be marked accordingly.

Swing Bridges at End of Dock

414 The loading on this connecting bridge is assumed to be 366 kg/m² (75 lb/ft²). If a heavier loading is anticipated or required, the plan is to be marked accordingly.

Section 5

ADDITIONAL ITEMS

Air Pipes under Safety Deck

501 The maximum draught of the dock (see R (F) 112) may be controlled by fitting air pipes under the safety deck and/or the centre pontoons. The length of these pipes will be dependent on the extent of the cushion of air desired. The pipes are to be of substantial thickness and rigidly supported in place.

Cranes

502 The structure of travelling cranes on the top deck is not included in the Society's survey unless specially desired.

The all-up weight of cranes, arrangement of wheels and rails are to be indicated on the plans, so that local strength requirements due to these loads may be taken into account.

Manholes

503 Sufficient manholes are to be cut in the safety deck, pontoon deck, transverses and girders in pontoons to provide adequate ventilation and access to all parts of the structure. The edges of holes are to be smooth. See also D 934.

Cofferdams

504 Compartments carrying oil are to be separated by cofferdams from those carrying fresh water. Cofferdams are to be suitably ventilated.

Coating

505 Particular attention is to be paid to the coating of the underwater portion of the dock. Full particulars are to be submitted for approval.

Section 6

TESTING

General

601 Each ballast tank, oil tank, and fresh water tank and cofferdam is to be separately tested by filling with water to the test head.

When water testing on the building berth may be undesirable, testing may be carried out afloat, provided any riveted shell seams in the bottom plating are tested with a high pressure hose on the berth. The testing afloat is to be so arranged that each tank can successively be examined whilst being subjected to a head of water equal to the maximum operational head as found from the hydrostatic curves.

When a preservative coating is to be applied to the internal structure of a tank, the water testing may take place after the application of the preservative, provided the structure is carefully examined to ensure that all welding and structural stiffening are completed prior to the application of the coating, and any riveted shell seams are tested with a high pressure hose on the berth before coating. The hose test of the riveted seams may be carried out from the outside to avoid wetting the tank structure.

The cause of any discoloration or disturbance of the coating is to be ascertained and any deficiencies repaired.

Compartments above the safety deck may be tested to an air pressure of 0,25 kg/cm² (3·5 lb/in²). Precautions are to be taken to ensure that this pressure is not exceeded.

Test Head

602 The test head for ballast tanks, as mentioned in the first sub-paragraph of 601 is to be 500 mm (20 in) above the top deck at side, but need not exceed twice the pressure head determined in accordance with R (F) 402.

Sinkage Trials

- 603 On the completion of the dock, sinkage trials shall be carried out in the presence of the Society's Surveyor. Fresh water tanks and the dock's fuel tanks shall be full, but ship-oil tanks are to be empty. The travelling cranes may be so positioned that the draughts forward and aft are equal. The density of the water shall be recorded.
 - (a) Normal Condition. All ballast water shall be emptied so far as possible, only rest-water remaining. The draughts forward and aft, port and starboard, shall be recorded. The readings on deflection meters shall be taken. The deflection of the dock along the top of keel blocks shall be measured.

Adjustment of the meters shall then be made, if necessary, so that they record this built-in permanent deflection in the normal condition. The light displacement shall be evaluated from these readings, and to obtain the light displacement, as defined in R (F) 108, the weight of any compensating ballast water must be added.

(b) Sagging Condition. Equal amounts of water shall be admitted to corresponding tanks on either side of the middle of the length, the depths increasing until the greatest depth is in the tanks at the middle of the length. The sagging bending moment so produced shall equal that evaluated in R (F) 203. The deflection meter readings shall be recorded and, by allowing for the permanent deflection, see sub-para. (a), the sagging deflection will be obtained.

Alternative arrangements to those described in (b) above will be specially considered.

604 When estimating the quantities of ballast water for 603 (b), the permissible difference in height of ballast water in adjacent compartments shall not exceed the pressure head for the compartments as laid down in R (F) 402.

Section 7

MACHINERY INSTALLATIONS

General

701 Items of machinery, such as boilers, pressure vessels, auxiliary engines, compressors, pumps, etc., essential to the operation of a floating dock are to be constructed and installed in general accordance with the relevant requirements of the Rules.

702 Fire extinguishing appliances, pumping arrangements, oil fuel and other piping systems are to be provided in accordance with the Rules so far as they may be applicable to floating docks.

703 The arrangements for discharging water ballast are to be such that not less than two pumps are available for pumping out each buoyancy compartment.

Electrical Installations

704 Electrical equipment constructed in accordance with the Rules will be accepted. Alternatively, consideration will be given to the acceptance of equipment constructed in accordance with a national or international standard for industrial equipment. In the latter case due consideration is

to be given to the ambient temperature and other ambient conditions expected in service and the necessary adjustments made to such items as permissible temperature rise.

705 In all other respects, e.g., the system of distribution, the installation is to comply with normal good electrical engineering practice and Chapter M is to be used as a guide for this purpose.

706 The following is to be carried out by the Surveyors and in accordance with Chapter M:—

- (i) Inspection and testing of electrical equipment.
- (ii) Installation of electrical equipment.
- (iii) Final testing of the electrical installation.

Plans

707 All necessary plans are to be submitted for approval before work is commenced.

Section 8

PERIODICAL SURVEYS

Annual Surveys

801 Docks should be surveyed afloat at intervals of approximately one year.

Special Surveys

802 Docks are to be subjected to Special Surveys at four-yearly intervals, the first four years from the date of build and thereafter from the date of the previous Special Survey.

PERIODICAL SURVEY REGULATIONS

HULL

Annual Surveys

803 The Surveyor is to satisfy himself as to the efficient condition of the following:—

Pontoon, safety and top working decks, exposed inner walls, shell plating above the light waterline, keel blocks and their foundations, casings, skylights, companion-ways and ladders, hatchways and manholes with their closing and securing arrangements, exposed self-docking connections, hinged gangways, mooring attachments, air pipes and overboard scuppers and discharges, guard rails and stanchions and rubbing fenders.

Special Surveys

804 The full requirements of an Annual Survey are to be complied with together with the following:—

The spaces between the safety and top working decks are to be cleared and cleaned as necessary and examined, lining and pipe casings are to be removed as required.

805 The Surveyor may require to ascertain by drilling or other approved means the thickness of the materials in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or materially reduced in scantlings are to be made good by materials of the approved scantlings and quality. Surfaces are to be recoated as necessary.

806 Where the inner surface of the bottom plating is covered with cement, asphalt or other composition the removal of this covering may be dispensed with, provided it be inspected, tested by beating or chipping, and found sound and adhering satisfactorily to the steel.

Pontoon and side wall tanks are to be cleaned and examined internally and tested by a head sufficient to give the maximum pressure that can be experienced in service.

807 Wood deck sheathing is to be examined; if decay or rot is found, or the wood is excessively worn, the wood should be renewed. Attention is to be given to the condition of the plating under the sheathing or other deck covering. If it is found that such coverings are broken or not adhering closely to the plating, sections should be removed as necessary to ascertain the condition of the plating.

808 For floating docks not more than 15 years old, oil fuel tanks forming part of the main structure need not be examined internally. When examining tanks internally the

Surveyor is to satisfy himself as to the condition of the pump suctions.

809 The Owners' proposals for examination of the underwater portion of the dock are to be submitted for consideration.

810 At the first Special Survey after the dock is 24 years old and at every 12 years thereafter or at the next Special Survey after the expiration of the latter period, the full requirements of a Special Survey stated above are to be complied with together with the following:—

In addition to the drilling required to ascertain local wastage, the outside plating of the walls and pontoons are to be gauged by drilling or other approved means to determine the amount of any general diminution in thickness. The gauging is to be done in at least two places in each strake of plating on each side within the amidship half-length.

All paint and rust is to be entirely removed before the plates are gauged by the Surveyor and the actual thicknesses are to be reported in detail. Where drilled plates are renewed the thickness of adjacent plates in the same strake should be reported.

MACHINERY INSTALLATION

811 For maintenance of class the boilers, machinery and electrical installations are to be submitted to periodical surveys in accordance with the relevant requirements of Chapters B and C, so far as these are applicable.

812 Where practicable, all sea connections should be opened up as part of the machinery survey but the Committee will be prepared to consider alternative proposals having regard to the circumstances of each case, provided full particulars are submitted.

25th January, 1968

ROTTALIATERI TREPLATION

R (G)-GUIDANCE NOTES ON PROPELLER-HULL CLEARANCES

Symbols

101 D = propeller diameter, in metres (feet).

R = propeller radius, in metres (feet).

L = length of ship, in metres (feet).

General

102 The following recommendations indicate the minimum clearances between the propeller and sternframe, rudder or hull that should be provided to minimize the possibility of propeller excited vibration.

SINGLE SCREW SHIPS

103 The clearances between the propeller and the rudder or sternframe should not be less than given in Table R (G) 1.1.

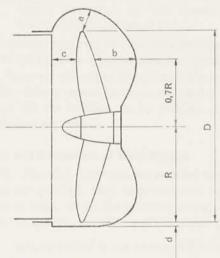


TABLE R (G) 1.1

NUMBER OF BLADES	a*	b*	c*	d
3	1,2k ₁ D	1,8k ₁ D	0,12D	0,03D
4	1,0k ₁ D	1,5k ₁ D	0,12D	0,03D
5	0,85k ₁ D	1,275k ₁ D	0,12D	0,03D
6	0,75k ₁ D	1,125k ₁ D	0,12D	0,03D

16th January, 1969

where

$$\begin{split} \mathbf{k_i} &= \left(0.1 + \frac{\mathsf{L}}{3050}\right) \left(\frac{2.56\,\mathsf{C_bH}}{\mathsf{L^2}} + 0.3\right) \\ \left(\mathbf{k_i} &= \left(0.1 + \frac{\mathsf{L}}{10\,000}\right) \left(\frac{28\,\mathsf{C_bH}}{\mathsf{L^2}} + 0.3\right)\,\mathrm{British}\right) \end{split}$$

C_b = moulded block coefficient at load draught.

H = maximum designed shaft horse power.

*Note. In no case should "a" be less than 0,10D, "b" less than 0,15D, or "c" less than the maximum thickness of the rudder. The thickness is to be measured at the 0,7R line above the shaft centreline.

TWIN SCREW SHIPS

104 The propeller tip-hull clearance should not be less than:—

3 blades: 1,2k2D but not less than 0,2D

4 blades: 1,0k2D but not less than 0,2D

5 blades: 0,85k₂D but not less than 0,16D

6 blades: 0,75k2D but not less than 0,16D

The clearance between the propeller and the shaft brackets or bossing should not be less than:—

3 blades: 1,2k,D but not less than 0,15D

4 blades: 1,0k2D but not less than 0,15D

5 blades: 0,85k2D but not less than 0,15D

6 blades: 0,75k,D but not less than 0,15D

where

$$\begin{aligned} & \mathsf{k_2} = \bigg(0.1 \, + \, \frac{\mathsf{L}}{3050}\bigg) \bigg(\frac{1,28\,\mathsf{C_b\,H}}{\mathsf{L^2}} + 0.3\bigg) \\ & \bigg(\mathsf{k_2} = \bigg(0.1 \, + \, \frac{\mathsf{L}}{10\,000}\bigg) \bigg(\frac{14\,\mathsf{C_b\,H}}{\mathsf{L^2}} \, + \, 0.3\bigg) \, \; \text{British} \, \bigg) \end{aligned}$$

 $C_{\rm b}={
m moulded}$ block coefficient at load draught,

H = maximum total designed shaft horse power installed.

H (G) GLODANCE HOTES ON PROPELLER-HULL CEPARATORS

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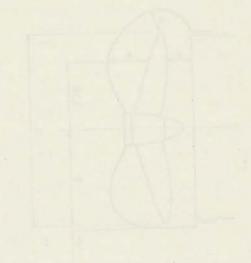
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R (H)—PROVISIONAL RULES FOR REPAIRS BY WELDING TO STEEL CASTINGS FOR CRANK SHAFTS

Section 1

General

101 Welded repairs are only to be undertaken when:—

- (a) the repairs are considered to be necessary and are approved by the Surveyor. Consideration must be given first to the blending of grooves formed by the removal of shallow defects, or to the machining of a surface where there is excess metal on the Rule dimension.
- (b) the specified maximum tensile strength of the steel is not in excess of 65 kg/mm² (41 ton/in²).
- (c) the maximum carbon content and the maximum carbon equivalent do not exceed 0,30% and 0,65% respectively (see Q 513).

Generally, approval for repairs by welding will only be given to rectify areas where random and accidental defects arise. Approval will not be given for (1) the rectification of repetitive defects caused by improper foundry technique or practice; (2) the building up by welding of surfaces or large shallow depressions.

Position and Dimensions of Weld Repairs

102 Provided Surveyors are satisfied that repairs by welding are justified, they may authorize repairs to the surfaces of webs, within the following limits:—

- (a) In general, the volume of the largest groove which is to be welded is not to exceed 3,2 t cm³ (t/2 in³) where t is the web axial thickness, in cm (in), The total volume of all grooves which are to be welded is not to exceed 9,6 t cm³ (1.5 t in³) per web.
- (b) The welds do not extend within the cross-hatched zones marked on Figs. R (H) 1.1 and R (H) 1.2 for fully-built and semi-built throws, respectively.
- (c) Larger repairs on balance weights may be permitted at the discretion of the Surveyor, provided such repairs are wholly contained within the balance weight and do not affect the strength of the web.

103 Weld repairs may also be authorized in the surface of the bore for the journal (or pin) within the following limits:—

(a) In general, the welds are to be not less than 125 mm (5 in) apart.

- (b) The welds are not located within circumferential bands of $\frac{t}{5}$ from the edges of the bores, nor at any position within the inner 120° arc of the bores, as cross-hatched on Figs. R (H) 1.1 and R (H) 1.2.
- (c) The volume of the largest weld is not more than about 1,1 t $\text{cm}^3\left(\frac{t}{6}\text{ in}^3\right)$ where t is the web axial thickness at the bore, in cm (in), and not more than three welds are to be made in any one bore surface.
- 104 At the discretion of the Surveyor, the size of a groove may be increased somewhat beyond the limiting sizes given in 102 (a) or 103 (c) if the removal of further metal will facilitate welding.

Repair Procedure

105 All castings are to be given a preliminary refining heat treatment prior to the commencement of weld repairs.

Only experienced welders are to make the repairs and, at any time, the Surveyors may require a welder to demonstrate his ability to make a sound weld.

- 106 After all defective material has been removed from a region, and this has been proved in the presence of the Surveyor by magnetic particle inspection or other suitable method, the depression may be suitably shaped to allow good access for welding.
- 107 Before welding, the material is to be preheated to a temperature of not less than 200°C. Where possible preheating should be carried out in a furnace. The preheat temperature is to be maintained until welding is completed and preferably until the casting is charged to the furnace for post-weld heat treatment.
- 108 Welds are to be made by the electric arc process in the downhand (flat) position using low hydrogen electrodes which will produce a deposited metal in no way inferior in properties to the parent metal.
- 109 On completion of the repairs the casting is to be given a suitable heat treatment, which is to consist of either full annealing or normalizing and tempering. Where small isolated defects are revealed after completion of full heat treatment as above, welding repairs followed by a stress

relieving treatment within the range 630 to 660°C may be permitted.

110 Welds are to be dressed smooth by grinding and proved by magnetic particle inspection. The surfaces of the welds and adjacent parent steel are to be free from harmful defect.

Documentation

111 The foundry is to provide Surveyors with a statement and/or sketch detailing the extent and location of the welded repairs made to each casting together with details of the heat treatment carried out at all stages.

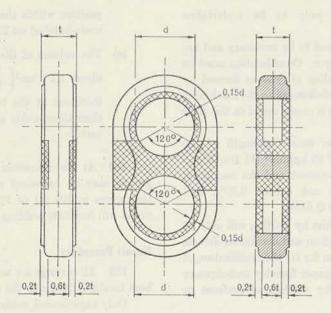


Fig. R (H) 1.1

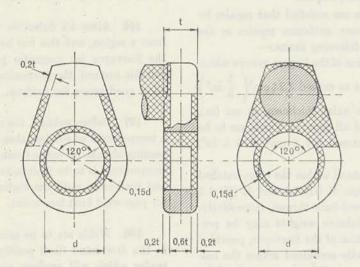


Fig. R (H) 1.2

16th June, 1966

R (J)—PROVISIONAL RULES FOR THE CLASSIFICATION OF TANKERS INTENDED FOR THE CARRIAGE OF LIQUID CHEMICALS IN BULK

General

The following Rules apply to ships having tanks integral with the hull, constructed generally in accordance with the provisions of the Society's Rules and Regulations for oil tankers, but which are intended specifically to carry liquid cargoes having hazards greater than or different from those associated with normal petroleum cargoes. The Rule arrangements do not, however, in general preclude the carriage of petroleum cargoes or of liquids having similar hazards.

Except in cases where the ship is intended to carry a specific chemical, the arrangements of tanks and pumping and piping systems are to be such as will permit the handling and simultaneous safe carriage of different liquid cargoes.

Sub-division and damage stability, also safety equipment for the ship and crew, are not covered by these Rules, and for these and any other special requirements of National or Port Administrations, reference should be made to the appropriate authority.

The Rules are sub-divided as follows:-

Part 1. Classification.

Part 2. Steel Ships.

Part 3. Pumping and Piping arrangements.

Part 4. Electrical Equipment.

Part 5. Tables of Cargoes.

PART 1

CLASSIFICATION

Section 1

General

101 The class notations which may be assigned by these Rules are related to ships having special features which make them suitable for the carriage of liquid cargoes which have been provisionally grouped in Tables R (J) 1, R (J) 2 and R (J) 3 (see Part 5) according to the degree and nature of the hazard involved. Cargoes may be added to these lists or may be transferred from one list to another as further experience may require.

Class Notations

102 Ships complying with the requirements of these Rules, including any special requirements for cargoes in Table R (J) 1, will be assigned the class 100A1 chemical

tanker—Type A and may also carry the cargoes listed in Tables R (J) 2 and R (J) 3.

- 103 Ships complying with the requirements of these Rules, including any special requirements for cargoes in Table R (J) 2, will be assigned the class 100A1 chemical tanker—Type B and may also carry the cargoes listed in Table R (J) 3.
- 104 Ships complying with the Rules for oil tankers, and the general cargo segregation and pump room ventilation requirements of these Rules, will be assigned the class 100A1 chemical tanker—Type C and may carry the cargoes listed in Table R (J) 3.
- 105 Where a ship is designed to carry only a specific cargo, the name of the cargo will be included in the class notation, e.g., 100Al sulphuric acid tanker, and the requirements will be modified as considered necessary for the particular hazards involved.
- 106 A list of cargoes for the carriage of which the ship has been approved will be attached to the Classification Certificate and this will be suitably modified where the additional requirements mentioned in the Tables have not been complied with.

Where cargoes are to be carried which are not on the approved list, it will be the Owners' responsibility to ensure that full particulars of such cargoes are forwarded to the Society for approval.

- 107 Additional notations may be given for the following features:—
 - (a) Number of different cargo segregations, e.g., "cs.4".
 - (b) Suitability of scantlings for high specific gravity cargoes, e.g., "sg 2,0".
 - (c) Provision of inert gas plant or system e.g., "ig".
 - (d) Tanks constructed of special corrosion resistant materials, e.g., stainless steel ("CR(ss)"), or lined with special corrosion resistant linings, e.g., rubber lining, ("CR (rubber lined)").
- 108 Where all cargo tanks on a ship are not adapted to comply with the requirements for one of the class notations given above, the notation will be suitably amended in the Register Book, e.g., 100Al chemical tanker—Type A 1-5 centre tanks; Type B 1-5 wing tanks.

Characteristics of Cargoes

109 Cargoes listed in Table R (J) I are those which require segregation from the sea by cofferdams, double bottoms, void spaces, etc., on grounds of their reactivity with water, their toxicity or the need for special materials of construction. In addition, such cargoes may have hazards which require special precautions to control the release of dangerous vapours and accidental release of dangerous liquids.

110 Cargoes listed in Table R (J) 2 are those which do not require segregation from the sea, but need significant increases in precautions to control the release of dangerous vapours and liquids as compared with normal petroleum cargoes.

111 In addition to the characteristics given in 109 and 110, the cargoes listed in Tables R (J) 1 and R (J) 2 may have a flash point (closed cup test) below 60°C (140°F) but may, in addition, have fire hazards in excess of those associated with normal petroleum cargoes, by virtue of wide flammable range or high vapour pressure, or auto-ignition temperature below 180°C (356°F), or a combination of these.

112 Cargoes listed in Table R (J) 3 are those which have hazards similar to and no greater than normal petroleum cargoes having a flash point (closed cup test) below 60°C (140°F).

Special Cargoes not listed in the Tables

113 Where it is proposed to carry a cargo the temperature of which requires to be maintained at or below ambient temperature for reasons of safe carriage, the temperature control equipment will be specially considered in relation to the physical and chemical characteristics of the cargo. The temperature control equipment in these cases is to be built under survey and a suitable additional notation assigned. (See D 70.)

In general, ships constructed in accordance with the Rules are not intended to carry cargoes having a temperature below 0°C (32°F).

114 There are individual special requirements for the following cargoes:—

Acrolein, Carbon Disulphide, Ethyleneimine, Ethyl Ether, Hydrochloric Acid, Hydrofluoric Acid, Propylene Oxide, Sulphur (molten), Phosphorous (molten), Tetraethyl Lead. PART 2

STEEL SHIPS

Section 2

PLANS

201 The following plans and information are additional to those required to be submitted by D 109 and D 4012:—

- 1. Ship General Arrangement giving location of:-
 - (a) hatches, tank cleaning and other openings to the cargo tanks.
 - (b) doors, hatches and other openings to enclosed spaces used for cargo handling.
 - (c) doors, hatches and other openings (e.g., vents) to accommodation and stores which give access to the cargo tank area.
 - (d) coated tanks or tanks constructed of special materials.
 - (e) proposed grouping of cargo tanks for cargo segregation purposes (coloured if necessary for ease in identification).
- Diagrammatic arrangements and capacity of ventilation arrangements to spaces to which access is necessary for cargo handling.
- Plans of fire protection, detection and extinction for the cargo tanks.
- 4. Where scantling reductions are desired in accordance with D 4016, particulars of tank coatings to be used with makers' product resistance list are to be submitted for consideration.

Section 3

SHIP ARRANGEMENT

General

301 All accommodation is to be arranged clear of the cargo tanks and adjacent cofferdams and cargo pump rooms in ships classed 100A1 chemical tanker—Type A or 100A1 chemical tanker—Type B.

302 Access openings are not to be arranged in forward bulkheads of accommodation. Access openings are also not to be arranged in sides of accommodation (wheelhouses excepted) within a distance from the aft end of the adjacent cargo tank of $\frac{L}{25}$ metres (feet) where L is the length of the ship, subject to a minimum of 4,5 m (15 ft) for the first two

tiers above the tank deck and a minimum of 3 m (10 ft) for the third tier and above. Windows or port lights to the accommodation in these areas are to be of the fixed type except for emergency escape windows, if fitted.

- 303 In special circumstances consideration may be given to the fitting of air locks in the sides of accommodation within the areas given in 302, provided that the requirements of 1706 are met. Air locks approved in these circumstances are to have self-closing doors, and arrangements should be made so that both doors cannot be opened simultaneously. Arrangements should be made to maintain a positive pressure in the air lock by ventilation from a safe space.
- 304 If a deckhouse is fitted in lieu of a poop, the front of the house should be extended in the form of a sill to the ship's side for a height of at least 600 mm (23.5 in) above the tank deck.
- 305 Two separate means of access from the open deck are generally to be provided to cofferdams, wing tanks and double bottom tanks adjacent to cargo tanks. Alternatively, the access to double bottom tanks may be via pump rooms, deep cofferdams or similar compartments but would be subject to special consideration. Within such spaces a minimum of 380 mm (15 in) clear access is to be obtained between stiffening members, and a minimum of 760 mm (30 in) between bulkhead plating.
- 306 Pipe tunnels, and duct keels to which access is normally required for operational purposes, are to be provided with means of access spaced not more than 60 m (200 ft) apart. In all cases, however, access is to be provided at each end of the tunnel or duct keel. Access openings to the foregoing spaces are to be from positions inside a pump room or deep cofferdam or from a trunk led to the open deck.
- 307 Arrangements should be made to provide easy access to below-deck cargo pump rooms. In general, ladders should not be arranged vertically, and intermediate platforms should be fitted at vertical intervals of about 6 m (20 ft). Ladders and platforms should have guard rails and permanent provision should be made for attaching a hoist for use in emergencies.
- 308 A continuous saveall is to be arranged on the weather deck, port and starboard, throughout the cargo tank area to contain minor spillage.
- 309 For ships classed 100A1 chemical tanker—Type C in which it is desired to fit midship accommodation, such accommodation is to be arranged one tier clear of the tank deck and there is to be no access or any other opening in

the tank deck in way of such accommodation, nor any direct communication between the accommodation and the space immediately above the tank deck. The space immediately above the tank deck under midship accommodation is not to be used as a workshop or as a storage space for combustible materials. If fresh water tanks are located in this space they are to be separated from the tank deck by a cofferdam, which may be open.

Cargo Segregation-General

- 310 Cargoes which could react hazardously with one another should be separated by a cofferdam, pump room, void space, empty tank or tank containing a mutually compatible cargo, and in addition there is to be corresponding segregation of the pumping and piping systems. The number of groups of tanks which comply with the foregoing will be recorded in the class (see R (J) 107(a)).
- 311 Proposals for grouping tanks to take account of cargo segregation should be clearly indicated on the plans.
- 312 For isolation of piping systems serving groups of tanks which may contain incompatible cargoes, see R (J) 1204.
- 313 Cofferdams are to be provided at the forward and after ends of the cargo spaces in accordance with D 4010, except that oil fuel bunker tanks will only be accepted in lieu of a cofferdam for ships classed 100A1 chemical tanker—Type C, i.e., for cargoes in Table R (J) 3.

Cargo Segregation Requirements applicable only to the class 100A1 Chemical Tanker—Type A

- 314 Tanks for the cargoes in Table R (J) 1 are to be fitted with a double bottom whose depth measured from top of keel to underside of double bottom tank top plating is not to be less than that required by D 904, or a depth of 410 + L/0,24 mm (16 + L/20 in) where L = length of ship in metres (feet), whichever is the greater. In no case, however, is the depth to be less than 760 mm (30 in). Sumps for drainage having a depth not greater than 200 mm (8 in) may be fitted having a maximum aggregate area of 1 per cent of the double bottom area of the tank served, provided that the double bottom structure in way of the sump is suitably reinforced. Attention is drawn to the fact that the regular carriage of full cargoes of high specific gravity may necessitate an increase in the height of double bottom.
- 315 Tanks for the cargoes in Table R (J) 1 are to be separated from the ship's side by at least 760 mm (30 in), but in the case of certain cargoes the minimum separation

is to be $\frac{\mathsf{B}}{5}$ metres (feet) where B is the breadth of the ship measured at the load waterline. For those cargoes requiring increased separation, reference should be made to column 8 of Table R (J) 1. The space or tank adjacent to the shell may be used for water ballast or cargoes in Tables R (J) 2 and R (J) 3, provided that the presence of different liquids in adjacent tanks does not constitute a reactivity hazard.

Section 4

MATERIALS OF CONSTRUCTION

- 401 Unless otherwise stated in column 7 of Table R (J) 1, the material of construction is steel complying with Chapter P.
- 402 Where stainless steel is an acceptable alternative to mild steel, it is generally to be of 18% Chromium, 12% Nickel, $2\frac{1}{2}\%$ Molybdenum austenitic stainless type, with a maximum of 0.03% Carbon. Higher carbon contents may also be accepted provided the steel is of the carbide stabilized type. Items such as castings which do not embody welding and are bolted to the structure may, however, have a maximum carbon content of 0.08%.
- 403 Where stainless steel tanks are arranged only to preserve product purity, the use of lower alloy stainless steels will be considered.
- 404 Stainless steel should not be used in the construction of cargo tanks intended for use intermittently as ballast tanks. Mild steel fittings are not permitted in stainless steel cargo tanks.

A combined structure of mild steel and stainless steel may be used in water ballast spaces, e.g., wing cofferdams, when special protective measures are taken to reduce bimetallic corrosion such as coating the stainless steel with a suitable high duty paint to reduce attack on the mild steel.

- 405 Proposals to protect the tank structure against corrosive attack from the cargo by the use of suitable linings will be specially considered.
- 406 Certain materials or their alloys, principally copper, and to a lesser extent aluminium, magnesium and zinc, are unsuitable for use with certain cargoes as given in the Tables. Where such cargoes are to be carried, the use of these materials is not advised in locations where they may come into contact with the cargo or its vapours. (See also R (J) 1702.)

Section 5

STRUCTURAL DESIGN

- 501 All-welded construction is to be employed in the cargo tank area and adjacent cofferdams, pump rooms and double bottoms.
- 502 The scantling reductions given in D 4016 may be given in association with suitable coatings, provided that the materials of construction are themselves resistant to the cargoes carried.
- 503 In general, D 40 applies to chemical tankers but, as this applies to ships carrying cargoes with a specific gravity not exceeding 1,025 and settings of pressure/vacuum valves in such ships are assumed to be set at positive/negative pressures not exceeding 0,14 kg/cm² (2 lb/in²) and 0,04 kg/cm² (0·5 lb/in²) respectively, increases in these values will generally entail modifications to the normal scantlings. In no case may tanks integral with the hull structure be used for a pressure valve setting exceeding 0,7 kg/cm² (10 lb/in²).
- 504 Where occasional cargoes are to be carried having a specific gravity greater than 1,025, tanks may be partially filled as an alternative to increasing the scantlings, provided the strength of the tank end structure is adequate for the forces which may be generated by movement of the cargo.
- 505 The minimum thickness, t, of mild steel structure within the range of the cargo tanks for ships under L = 90 m (295 ft) is to be derived from the following formula, but is not to be less than 7 mm (0.275 in):—

t = 5.6 + 0.038L mm (t = 0.22 + 0.00046L in) where L = length of ship in metres (feet).

506 The section modulus of inner bottom longitudinals in ships fitted with double bottoms under the cargo tanks is not to be less than:—

$$\frac{I}{y} = \frac{\text{s S}^2}{120} (\text{h} + 0.9) \text{ cm}^3 \qquad \left(\frac{\text{s S}^2}{2736} (\text{h} + 3) \text{ in}^3\right)$$

- S = span, in metres (feet), measured between effective supports.
- h = vertical distance, in metres (feet), to the highest point of the tank excluding the hatchway but including expansion trunks if fitted.
- s = spacing in mm (in).

Where specific gravity, ρ , of the liquid being carried exceeds 1,025, the modulus is to be multiplied by the factor $\frac{\rho}{1,025}$. See also 504.

Heated Cargoes

507 Where cargoes are to be heated and the sides and/or bottom of the heated tank are not in direct contact with the sea, a thermal stress investigation may be necessary if the steel temperature of the cargo tanks exceeds 50°C (122°F). In such cases calculations giving estimated temperatures for the hull structure should be submitted, based on a sea temperature of 0°C (32°F) and an air temperature of 5°C (41°F). Depending on the results of such investigations it may be necessary to limit the still water bending moment in such conditions.

A thermal stress investigation will generally not be necessary in ships carrying cargoes heated to temperatures approaching 80°C (176°F) where the sides and/or bottom of the heated tank are in direct contact with the sea, provided the longitudinal bulkheads and ship sides are transversely framed.

508 Where heating duets are integral with the tank structure, they are to be designed to withstand a head equal to the maximum pressure in the heating system, but in no case less than that imposed by the highest specific gravity cargo for which the tanks have been designed. See also R (J) 1501 (d).

Stainless Steel Construction

509 The thickness of plating forming the boundaries of cargo tanks, excluding the top and bottom strakes of longitudinal bulkheads is not to be less than:—

$$t=0{,}004\,\text{s}\,\sqrt{\frac{\rho\,h}{1{,}025}}+\text{Kc}\,\,\text{mm}$$

$$\left(\mathsf{t} = 0.0022 \, \mathsf{s} \, \sqrt{\frac{\rho \, \mathsf{h}}{1.025}} + \mathsf{Kc in} \right)$$

where s = stiffener spacing, in mm (in), of welded stiffeners, or breadth, in mm (in), of flange or web, whichever is the greater, for corrugated bulkheads.

> ρ = specific gravity of the liquid to be carried and is not to be taken as less than 1,025. See also 504.

> h = vertical distance, in metres (feet), from a point one-third of the height of the plate above its lower edge to the highest point of the tank excluding the hatchway but including expansion trunks if fitted.

For the crowns and upper strakes of cargo tanks, the thickness of the plating is not to be less than that which would be obtained with an overflow

$$2.0 \, \times \frac{\rho}{1,025} \,\, m \qquad \left(6 \cdot 5 \, \times \frac{\rho}{1 \cdot 025} \,\, ft \,\right)$$

above the crown of the tank.

Values of Kc for solid stainless steel plating and stainless clad steel plating are as follows:—

(a) Bulkheads exposed to the cargo on both sides, e.g., single plate transverse bulkheads and centreline bulkheads:

Kc = 2 mm (0.08 in) for solid stainless steel (stainless clad steel not applicable).

(b) Bulkheads exposed to the cargo on one side and dry on the other side (or coated in a water ballast tank), e.g., longitudinal cofferdam bulkheads adjacent to the shell, top of tanks (or exposed decks) or cofferdam transverse bulkheads with one side in a dry space:

 $\mathsf{Kc} = 1.0 \; \mathrm{mm} \; (0 \cdot 04 \; \mathrm{in})$ for solid stainless steel

= 1,5 mm (0.06 in) for stainless clad steel.

(c) Bulkheads exposed to the cargo on one side and to water ballast on the opposite side, e.g., those items mentioned in (b), but which form the boundaries of both ballast and cargo tanks (see also R (J) 404):

Kc = 1.0 mm (0.04 in) for solid stainless steel

= 2,0 mm (0.08 in) for stainless clad steel.

If the mild steel side of stainless clad plating is suitably coated, Kc may be 1,5 mm (0.06 in).

(d) Tank bottoms where the underside is accessible and dry:

Kc = 1.5 mm (0.06 in) for solid stainless steel= 2.0 mm (0.08 in) for stainless clad steel.

(e) Tank bottoms where the underside is accessible and in contact with water ballast (see R (J) 404):

Kc = 1,5 mm (0.06 in) for solid stainless steel = 2,5 mm (0.10 in) for stainless clad steel.

(f) Tank bottoms where the underside is inaccessible due to presence of integral heating ducts:

Kc = 2.0 mm (0.08 in) for solid stainless steel= 3.0 mm (0.12 in) for stainless clad steel.

510 The minima given in 505 may be reduced by (2,5-Kc) mm $((0\cdot10-\text{Kc})$ in) according to the locations in 509, but in no case is the final overall thickness to be less than 7 mm $(0\cdot28$ in). See also 513.

511 The thickness of clad steel includes the cladding, and the thickness of the cladding itself is to be at least 1.5 mm (0.06 in) at the tank sides and top and 2.0 mm (0.08 in) at the tank bottom.

512 Heating ducts integral with tanks constructed from solid stainless steel plating may be of mild steel only where a thermal fluid of a type which is non-corrosive to steel is used for the heating medium. If fresh water is used then means of monitoring for the presence of rust should be provided.

513 Where high proof solid stainless steels are used, special consideration will be given to the scantlings in relation to the material properties, subject to an overall minimum for the thickness of plating of 6,5 mm (0·26 in) for the top and sides of tanks and 7,0 mm (0·28 in) for the bottoms of tanks.

Welding inside Cargo Tanks

514 All fillet welds in cargo tanks are to be double continuous.

All boundary connections of transverse bulkheads are to be formed by complete penetration welds.

To prevent inter-tank leakage, where longitudinal stiffeners pass continuously through bulkheads, a scallop, the ends of which are to be carefully welded all round, is to be arranged in each longitudinal stiffener adjacent to the bulkhead. Alternatively, complete penetration welds are to be arranged at the connection of each longitudinal stiffener to adjacent plating for a minimum distance of 150 mm (6 in) on each side of bulkheads. This requirement does not apply to deck stiffening.

Section 6

TESTING

601 The requirements of D 52 apply except that:—

- (a) Leak testing may be conducted after the application of a primer.
- (b) Subject to careful inspection by the Surveyors prior to coating, the complete protective coating system may also be applied to fabricated units having butts and seams welded by automatic processes, provided that the welds made on the berth are left uncoated except for a primer until the leak test has been completed. All damage to coatings during erection will require to be made good.
- (c) Each cargo tank bulkhead is to be hydraulically tested by filling suitably located tanks, cofferdams

or double bottoms with water. The test head is to be 2,45 m (8 ft) above the highest point of the tank excluding hatchways, except that when cargo tanks are designed for cargoes having a specific gravity greater than 1,025, the test head is to be increased to $2.0 \times \text{sg}$ m $(6.5 \times \text{sg}$ ft). The test may be carried out with the ship afloat.

Quality Control

602 The following requirements are intended to supplement the amount of non-destructive testing normally carried out by the shipyard:—

- (a) All butt weld crossings of cargo tank bulkheads which are made on the berth are to be radiographed.
- (b) Where longitudinals stop at bulkheads, a minimum of 10 per cent of the bulkhead boundary connection is to be crack detected.
- (c) Where longitudinal stiffeners pass continuously through the bulkhead, 100 per cent of the bulkhead boundaries on the bottom 10 per cent of the depth of the bulkhead is to be crack detected in addition to the requirements of (b) above.

Section 7

VENTILATION OF CARGO HANDLING SPACES AND SPACES ADJACENT TO CARGO TANKS

701 Permanent mechanical ventilation is to be provided for all enclosed spaces containing pumps, valves or piping, used for controlling loading, discharging and gas freeing. The ventilation system for such spaces is to be independent of all other systems.

702 In below-deck pump rooms the system is to be of the mechanical extraction type, and ducting is to be arranged to permit alternative extraction from the top and bottom of the space, the former being taken as excluding access trunks. In the case of extraction from the bottom of the space, arrangements are to be made for extraction from both above and below the floor plates and from communicating pipe tunnels (if fitted).

703 The vent exits from pump rooms are to discharge at least 10 m (33 ft) away from windows and access openings to accommodation. The height of vent inlets and exits is not to be less than 4,5 m (15 ft) above the tank deck. Regard is to be taken of the positions of cargo tank vent exits when locating the inlets for pump room vents. (For distance from mechanical ventilation inlets see R (J) 1707.)

- 704 The mechanical ventilation system is to be capable of being operated from outside the compartment being ventilated, and a notice is to be fixed near the entrance stating that no person is to enter the space until the ventilation system has been in operation for at least 15 minutes. (For fans and fan motors see R (J) 1707.)
- 705 Other spaces which contain cargo piping, valves, etc., to which regular access is not normally required for operational purposes, also spaces adjacent to cargo tanks, are to be fitted with means of attaching portable mechanical ventilating equipment. The equipment is to be capable of circulating sufficient air to the compartment concerned to give at least 15 air changes per hour. Alternatively, if permanent ventilating equipment with suitable ducting is employed for such spaces, a minimum of 8 air changes per hour will be accepted.
- 706 For ships to be classed 100A1 chemical tanker—Type A (cargoes in Tables R (J) 1, R (J) 2 and R (J) 3), pump room ventilation is to consist of not less than 45 air changes per hour, based on the gross volume of the space including access trunking and communicating pipe tunnels (if fitted).
- 707 For ships to be classed 100A1 chemical tanker—Type B (cargoes in Tables R (J) 2 and R (J) 3), pump room ventilation is to consist of not less than 30 air changes per hour based on the gross volume of the space including access trunking and communicating pipe tunnels (if fitted).
- 708 For ships to be classed 100Al chemical tanker—Type C (cargoes in Table R (J) 3), pump room ventilation is to consist of not less than 20 air changes per hour based on the gross volume of the space including access trunking and communicating pipe tunnels (if fitted), and the distances and heights of vents given in 703 are not generally applicable.

Section 8

VAPOUR DETECTION

801 To enable vapour samples to be obtained safely, a permanently fitted pipe system to which either permanent or portable vapour detection equipment may be attached, is to be fitted to all enclosed spaces containing cargo pumps, pipes and valves regularly used by personnel. The pipe system is to have a sufficient number of sampling points to to give a representative coverage of the space concerned.

- 802 If remote reading vapour detection systems are used, they must not allow vapour to enter a non-dangerous space.
- 803 Portable detection equipment is to be provided for use in other spaces adjacent to cargo tanks, e.g., cofferdams, double bottoms, tunnels, etc.
- 804 Two sets of portable instruments for detection (and measurement where practicable) of the specific vapours in question are to be provided for the following:—
 - (a) flammable vapours,
 - (b) toxic vapours,
 - (c) oxygen content.

If instruments are provided which combine some of these functions, then the number of such instruments required may be appropriately reduced.

Section 9

FIRE FIGHTING IN THE CARGO TANK AREA

- 901 Fire fighting equipment suitable for all types of cargoes being carried is to be carried on board.
- 902 A fixed installation, or combination of installations, is to be provided for fire fighting in the cargo tanks and in the tank deck area. A nozzle suitable for spraying water is to be provided for use with each hose on the tank deck.
- 903 If the vessel is designed to supply inert gas for permanent inerting of all cargo spaces, consideration will be given to acceptance of such a fixed system as an alternative for the protection of cargo tanks, provided that there is sufficient capacity.
- 904 Fixed installations for fire fighting on the deck shall be capable of reaching all parts of the tank deck.
- 905 Cargo pump rooms are to be provided with a fixed remote controlled fire extinguishing system. In addition, two portable extinguishers of approved type are to be provided in each space.

Protective Clothing

906 Protective clothing for fire fighting, also equipment for protection of crew engaged in loading and discharging operations and equipment permitting personnel to enter gas-filled compartments, are to be in accordance with the requirements of the National Authority.

PART 3

PUMPING AND PIPING ARRANGEMENTS

General

For ships which are intended to carry the cargoes listed in Tables R (J) 1 and R (J) 2, the following requirements, and the requirements of E 11, irrespective of the flash point of the cargo, are to be complied with where applicable. See also R (J) 105.

For ships which are intended to carry the cargoes listed in Table R (J) 3, the requirements of E 11, irrespective of the flash point of the cargo, are to be complied with where applicable. See also R (J) 105.

Section 10

PLANS

1001 The following diagrammatic plans are to be submitted for consideration, in addition to those required by E 101, where applicable:—

Pumping arrangements at forward and after ends of the ship.

Drainage arrangements of cofferdams and pump rooms and other compartments within the range of, and adjacent to, the cargo tanks.

General arrangement of cargo piping in tanks, on deck and in pump rooms.

Cargo tank venting and sounding arrangements.

Arrangements of inert gas system (where fitted), and arrangements for gas freeing of cargo tanks and cargo handling systems.

Arrangement of cargo heating systems (where fitted).

A general arrangement of the ship showing the location of the controls and instruments.

Arrangements of the control station(s) showing layout of controls and instruments.

Details of controls and instruments.

Section 11

GENERAL REQUIREMENTS

Materials

1101 All materials used in the pumping and piping systems are to be suitable for use with the intended cargoes.

Protective coating of pipes of non-corrosion resistant material would not normally be acceptable for corrosive cargoes.

Design

1102 All piping, valves and fittings are to be suitable for the maximum pressure to which the system can be subjected, but not, in any case, less than a pressure of 10,5 kg/cm² (150 lb/in²).

Piping subject to pressure is to be of seamless or other approved type and is to comply with the requirements of E 5.

1103 Pumping and piping systems, including the cargo pumps, are to be made and installed under survey.

Ballast Tanks and Void Spaces

1104 Clean ballast tanks and void spaces within the range of the cargo tanks are not to be connected to cargo pumps or have any connections to the cargo system. A separate ballast/bilge pump is to be provided for dealing with the contents of these spaces. This pump is to be located in the cargo pump room or other suitable space within the range of the cargo tanks.

1105 Consideration will be given to connecting double bottom and/or wing tanks, which are in the range of the cargo tanks, to pumps in the machinery space where the tanks are completely separated from the cargo tanks by cofferdams, heating ducts or containment spaces, etc.

1106 Bilge, ballast and oil fuel lines, etc., which are led to pumps in the machinery space, or to other spaces outside the cargo tank range, are not to pass through cargo tanks, although, in general no objection will be made to these lines being led through the clean ballast or void tank spaces within the range of the cargo tanks.

• 1107 Air and sounding pipes to wing and double bottom tanks which are adjacent to cargo tanks are to be led to the open deck and are not to pass through cargo tanks.

1108 Arrangements are to be provided to enable double bottom tanks situated below cargo tanks to be filled with water ballast to assist in the gas freeing of these tanks.

Pump Room Drainage

1109 Below-deck pump room bilge systems for cargoes listed in Table R (J) 1 are to be capable of being operated from the weather deck.

Section 12

CARGO HANDLING SYSTEM

General

1201 Stand-by means for pumping out each cargo tank are to be provided.

1202 Where cargo tanks are provided with single deep well pumps, or submerged pumps, it will be necessary to provide alternative means for emptying the tanks in the event of the failure of a pump.

Portable submersible pumps may be provided on board for this purpose, but the arrangements are to be such that a portable pump could be safely introduced into a full or part-full tank. Details of the arrangements are to be submitted.

Location of Cargo Pumps

1203 Where column 8 of Table R (J) 1 cross-refers to this paragraph, the cargo pumps are to be located in the tanks or on deck.

Cargo Segregation

1204 Isolation of piping systems which serve tanks containing incompatible cargoes (see R (J) 310 to R (J) 313) are to be made by means of removable pipe lengths and blank flanges. Isolating shut-off valves, single or double, or spectacle flanges are not acceptable as equivalent arrangements.

Cargo piping is not to be led through any tank containing a cargo which is incompatible with that contained in the tank served by such piping unless it is encased in a pipe tunnel.

Connections to Cargo Tanks

1205 Cargo tank deck filling connections are to be provided with pipes internal to the tanks and led to the bottom of the tanks.

1206 Where cargo suction and/or filling lines are led through cargo tanks, or through other spaces situated below the weather deck, the connection to each tank is to be provided with a valve situated inside the tank and capable of being operated from the deck.

In the case of cargo tanks which are located adjacent to below-deck pump rooms, or pipe tunnels, the deck operated valves may be located in these spaces at the bulkhead.

In any case, however, not less than two isolating shutoff valves are to be provided in the pipe lines between the tanks and the cargo pumps.

1207 Pumps which are connected to the cargo system or tanks, directly or indirectly, are not to be connected to fire mains or pipe lines which are connected to pumps in the machinery space.

1208 Means are to be provided to enable the contents of the cargo lines and pumps to be drained to a cargo tank or other suitable tank.

Pump room drain tanks are to be of the closed type with air and sounding pipes led to the open deck.

Tank Openings

1209 Cargo tank access hatches and all other openings to cargo tanks, such as ullage and tank cleaning openings and restricted sounding devices (see R (J) 1405), are to be located on the weather deck.

Remote Control Valves

- 1210 Valves on deck and in pump rooms which are provided with remote control, are, in general, to be capable of local manual operation independent of the remote operating mechanism.
- 1211 Where the valves and their actuators are located inside the cargo tanks, two separate suctions are to be provided in each tank.
- 1212 All actuators are to be of a type which will prevent the valves from opening inadvertently in the event of the loss of pressure in the operating medium.

Indication is to be provided at the remote control station showing whether the valve is open or shut.

- 1213 Materials of construction of the actuators and piping inside the cargo tanks are to be suitable for use with the intended cargoes.
- 1214 Compressed air is not to be used for operating actuators inside cargo tanks.
- 1215 The actuator operating medium in hydraulic systems is to have a flash point of 60°C (140°F) or above (closed cup test) and is to be compatible with the intended cargoes.
- 1216 The design of the actuators is to be such that contamination of the operating medium with cargo liquid cannot take place under normal operating conditions.

Where the operating medium is oil, or other fluid, the supply tank is to be located as high as practicable above the level of the top of the cargo tanks, and all actuator supply lines are to enter the cargo tanks through the highest part of the tanks. Furthermore, the supply tank is to be of the closed type with an air pipe led to a safe space on the open deck and fitted with a flameproof wire gauze diaphragm at

its open end. This tank is also to be fitted with a high and low level audible and visible alarm, and means are to be provided for detecting the presence of cargo liquid in the operating medium.

1217 It is recommended that for remote control valves, not arranged for manual operation, emergency means be provided for operating the valve actuators in the event of damage to the main hydraulic circuits on deck. In the case of valves located inside cargo tanks this could be achieved by ensuring that the supply lines to the actuators are led vertically inside the tanks from deck, and that connections, with the necessary isolating valves, are provided on deck for coupling to a portable pump carried on board.

Cargo Handling Controls

1218 Electrical measuring, monitoring control and communication circuits located in dangerous spaces are to be intrinsically safe.

1219 The handling controls and instruments are to be arranged for safe and easy operation. They may be grouped at a number of control stations or at one main control station.

1220 If a cargo handling control station is enclosed and is located in a dangerous space (see R (J) 1706), it is to be enclosed by gastight steel bulkheads and separated from the tank deck by a cofferdam.

In addition, where the entrance leads from a dangerous space, the control station is to be pressurized and the entrance is to be fitted with an air lock provided with independent means of pressurization.

Air locks are to have gastight self-closing doors arranged so that both doors cannot be opened simultaneously. Door sills are not to be less than 600 mm (24 in) in height.

- 1221 Pipes containing or likely to contain fluids, which may cause a hazard are to be excluded from enclosed control stations.
- 1222 A satisfactory means of communication is to be provided between cargo handling stations, open deck, the bridge and the machinery space.
- 1223 The cargo handling controls and instrumentation are, so far as possible, to be separate from the propulsion and auxiliary machinery controls and instrumentation.

Section 13

CARGO TANK VENTING ARRANGEMENTS

General

1301 Each cargo tank is to be fitted with a vapour pipe (or pipes) led from the highest part (or parts) of the tank and connected through pressure vacuum valves to vapour lines led up the mast or other suitable posts.

The outlets are to be arranged to discharge the vapour in an upward vertical direction and are to be fitted with a readily removable flameproof wire gauze diaphragm protected from the weather.

1302 Individual vents may be combined into a common riser, provided that regard is given to cargo segregation requirements.

1303 For the cargoes listed in Table R (J) 1, connections for returning the vapour to shore when loading cargo are to be provided.

1304 Suitable drainage arrangements are to be provided in the vapour lines.

Location of Vapour Outlets

1305 The height of vapour outlets are not to be less than 4 m (13 ft) above the weather deck or above the fore and aft gangway if fitted within 4 m (13 ft) of the gangway. The height may be reduced to 2,5 (8 ft 6 in) where the vapour outlets are fitted with an approved type of high velocity venting head. Further, the vapour outlets are also to be arranged not less than 10 m (33 ft) from the nearest air intakes or openings to accommodation and enclosed working spaces and to possible sources of ignition.

1306 For certain cargoes, as indicated in column 8 of Table R (J) 1 and column 7 of Table R (J) 2, the height of vapour outlets are not to be less than 6 m (20 ft) above the weather deck or above the fore and aft gangway if fitted within 6 m (20 ft) of the gangway. The height may be reduced to 4 m (13 ft) where the vapour outlets are fitted with an approved type of high velocity venting head. Further, the vapour outlets are also to be arranged not less than 15 m (49 ft) from the nearest air intakes or openings to accommodation and enclosed working spaces and to possible sources of ignition.

1307 The sizes of the vapour pipes and associated valves are to be sufficient to ensure that the cargo tanks will not be subject to over-pressure during loading or under-pressure when discharging.

When sizing the vapour lines, the quantity of vapour liberated from the cargo during loading is to be taken into consideration as well as the maximum loading rate.

- 1308 The pressure vacuum valves may be provided with by-pass valves for use when loading cargo.
- 1309 Where the vacuum side of a pressure vacuum valve draws direct from the atmosphere, the inlet from the atmosphere is to be provided with a flameproof wire gauze diaphragm.

Vacuum Relief

1310 Where the cargo is required to be carried under an inert gas blanket, vacuum relief is to be obtained from a supply of inert gas. (See also Inert Gas Systems, R (J) 16.)

Section 14

CARGO TANK LEVEL GAUGING EQUIPMENT

- 1401 Each cargo tank is to be fitted with suitable means for ascertaining the liquid level in the tank.
- 1402 Closed sounding devices of an approved type, which do not permit the escape of cargo to the atmosphere, are to be fitted to those tanks which are intended to carry the cargoes listed in Table R (J) 1.
- 1403 Where indicated in column 8 of Table R (J) 1, the tanks are to be provided with a high level audible and visible alarm.
- 1404 In addition to the high level alarm required by 1403 the tanks of certain cargoes, as indicated in column 8 of Table R (J) 1, will require to be provided with an independent high level alarm device giving audible and visible warning of over-filling and capable of closing the tank filling valve. Alternative means of avoiding accidental spillage will be specially considered.
- 1405 Restricted sounding devices, which may permit a limited amount of vapour to escape to the atmosphere when being used, would be accepted for cargo tanks which are intended to carry the cargoes listed in Table R (J) 2.

The restricted sounding device should be so designed as to minimize sudden release of vapour under pressure and the possibility of liquid spillage on deck. 1406 Proposals to use indirect sounding devices which do not penetrate the tank plating will be specially considered.

Section 15

CARGO HEATING ARRANGEMENTS

General

- 1501 Where heating systems are provided for the cargo tanks, the following requirements are to be complied with:—
 - (a) The heating medium is to be compatible with the cargoes to be heated.
 - (b) Isolating shut-off valves are to be provided at the inlet and outlet connections to the heating circuit of each tank.
 - (c) A test cock and a connection for either compressed air or inert gas is to be provided for "blowing through" the heating circuits of each tank. The cargo heating circuit should be blown through and hydraulically tested each time before loading a toxic cargo which requires to be heated.
 - (d) A higher pressure is to be maintained within the heating circuit than the maximum pressure head which can be exerted by the contents of the cargo tank on the circuit. Alternatively, when the heating circuit is not in use, it may be drained and blanked.
 - (e) Heating supply and return lines are not to penetrate the cargo tank plating other than on the top of the tank, and the main lines are to be run above the weather deck.
 - (f) Means are to be provided for detecting the presence of chemicals in the return lines.
 - (g) Steam heating return lines from cargo tanks which are intended to carry toxic cargoes are to be led to an observation tank located on the open deck. Alternatively, the observation tank may be located in the machinery space provided that it be of the closed type and is fitted with an air pipe led to a safe space on the open deck. Safe means are to be provided to remove contaminated heating medium from the observation tank.
 - (h) Means are to be provided for ascertaining the temperature of the cargo in the tanks.
- 1502 Proposals to use cargo heating systems which employ thermal oil or hot water will be specially considered.

PART 4

ELECTRICAL EQUIPMENT

INERT GAS SYSTEMS

General

1601 Where it is intended to transport cargoes which require to be carried under an inert gas blanket, and/or where the space adjacent to the cargo tanks requires to be inerted, it will be necessary for an inert gas generator and/or inert gas storage vessels to be fitted on board for dealing with any losses during the voyage.

1602 The inert gas should be suitable for use with the cargoes to be carried.

1603 Means are to be provided for indicating the pressure in the vapour space of each cargo tank and inerted space.

1604 Meters are to be provided on board for checking the amount of oxygen in the generated inert gas and in the inerted spaces.

Piping Systems

1605 Where an inert gas system is fitted the following requirements are to be complied with:—

- (a) The necessary piping system is to be provided on board for distributing the inert gas, and connections are also to be provided for receiving or returning inert gas to shore.
- (b) Arrangements are to be provided for preventing the back flow of cargo vapour into the inert gas system.

Where the inert gas generating plant is located in the machinery space, or other space outside the range of the cargo tanks, two non-return valves, or an equivalent device, are to be fitted in the inert gas main where it leaves the machinery space.

- (c) The arrangements are to be such that spaces being inerted can be isolated and the necessary controls and relief valves, etc., are to be provided for preventing over-pressure in these spaces.
- (d) Gas freeing and purging connections between the inert gas system and the cargo system are, in general, to be made by means of portable pipes which should be removed when not in use and the connections suitably blanked.

Cross-reference

1606 See also R (J) 8-Vapour Detection.

Section 17

General Requirements

1701 Where flameproof or intrinsically safe electrical equipment is required, the equipment is to be certified in accordance with the relevant National or International Standards for use in atmospheres of the highest class or group amongst those for which the class notation is to be assigned.

Alternatively, if the ship is designed to carry only a specific cargo (see R (J) 105), it will be sufficient for the equipment to be certified for the atmosphere concerned.

age materials normally used in electrical equipment, special consideration is to be given to the choice of materials for such items as conductors and insulation located in dangerous spaces. So far as practicable, materials used in electrical equipment, such as copper or aluminium, should be so protected as to prevent contact with the gases, vapours or chemicals (e.g., enscapsulation may be necessary).

Among the chemical cargoes which cause damage to electrical materials are:—

Acrylonitrile, Ammonia, Carbon Tetrachloride, Diamine Ethyl, Monoethanolamine, Morpholine, Phenol, Potassium (aqueous solution), Propylene Dichloride, Propylene Oxide, Soda (aqueous solution), Styrene Monomer.

1703 Cables and cable ducts should be suitably sealed at the ends to prevent transfer of gas or vapour from one space to another.

1704 For ships carrying cargoes listed in Table R (J) 3 (see R (J) 104), the requirements of Chapter M, including M 16, are to apply.

1705 For ships carrying cargoes listed in Tables R (J) 1 and R (J) 2, the following Rules are to apply in addition to the requirements of Chapter M, including M 16, (see also R (J) 105).

1706 The following are considered to be dangerous spaces:—

- (a) Zones on open deck within 4,5 m (15 ft) of any tank outlet, vapour outlet or cargo tank.
- (b) Zones on open deck up to a height of 4,5 m (15 ft) over all cargo tanks, including wing ballast tanks to the full width of the vessel, plus 4,5 m (15 ft) fore and aft.

 $1707\,$ The inlets of ventilation systems for non-dangerous spaces are to be at least 10 m (33 ft) from openings or ventilation outlets of dangerous spaces or from any gas or vapour outlet.

Fan motors are to be arranged outside the vented compartment and outside the ducting, and are to be of flameproof enclosure where situated in dangerous spaces. Fan impellers are to be so constructed as to prevent sparking or the inducement of static charges within the trunking.

1708 Where the cargo presents a degree of hazard from the point of view of reaction with other materials such that flammable gas or vapour may be evolved, requirements additional to the above may be required, dependent on the characteristics of the gas or vapour in question.

PART 5

TABLES OF CARGOES

Notes.

- (a) The tables of cargoes have been prepared on considerations of safety. Arrangements for conserving the quality of the cargo are the responsibility of the Owner.
- (b) An x in the appropriate column indicates a significant hazard. The absence of an x, however, does not mean that no hazard exists under that heading.
- (c) Fire hazard is indicated in column 3 when the flash point (closed cup test) is below 60°C (140°F). However, in the last column particulars may be given when the auto-ignition temperature is less than 180°C (356°F) and/or there is a wide flammable range or high vapour pressure.
- (d) Reactivity with the environment or self-reactivity have not been indicated, since such cargoes would require to be inerted and/or inhibited, as indicated in the last column.
- (e) Chemical Tankers Types A, B and C may carry:—
 - (i) normal petroleum cargoes and mineral oils such as crude oil, fuel oil, diesel oil, lubricating oil and refined spirits such as gasoline, jet fuel, kerosene, etc.
 - (ii) wines or vegetable and edible oils such as castor oil, coconut oil, cotton seed oil, fish oil, latex, olive oil, palm oil, peanut oil, soya bean oil, sperm oil, tall oil, etc.

1	2	3	4	5	6	7	8
Name Formula	Specific Gravity where over 1,025	Fire Hazard	Vapour Hazard	Skin Contact Hazard	Water Reac- tivity Hazard	Unsuitable Materials	Additional requirements, information, etc.
ACETIC ACID CH ₃ COOH	1,05	x	-	x	i —	Mild Steel	Stainless Steel or Aluminium acceptable
	1,08		х	х	х	Mild steel	Stainless Steel or Aluminium acceptable
ACETONE CYANOHYDRIN (CH ₃) ₂ C(OH)CN	-	-	x	×	_	-	Stabilized for shipment See also 315 (B/5 applies), 1203, 1403 and 1404
ACETONITRILE CH ₃ CN		х	х	х	-	Cu	See 1306
ACRYLONITRILE CH ₂ CHCN	_	х	х	х		Mg Al Zn	Inhibited for shipment See also 1306 and 1403
ALLYL ALCOHOL CH ₂ CHCH ₂ OH		х	х	х	-	-	See also 1306, 1403 and 1404
ALLYL CHLORIDE CH₂CHCH₂CI	-	×	×	х	:	Mild steel if water present	B.P. 45°C (113°F) Nickel acceptable See also 1306, 1403 and 1404
ANILINE $C_6H_5NH_2$	_	=	х	х		-	See 1306, 1403 and 1404
n or iso-BUTYL ACRYLATE $\label{eq:ch2CHCOOC_4H9} \text{CH}_2\text{CHCOOC}_4\text{H}_9$	-	х	_	х	_	-,	Inhibited for shipment
CARBOLIC OIL (containing napthalene, phenol and cresols)	Abt 1,1	_	х	х	-	_	See 1306, 1403, and 1404
CHLOROHYDRINS (crude)	1,2	х	х	х		-	See 1306, 1403 and 1404
CHLOROSULPHONIC ACID ClSO₂OH	1,77	-	х	х	х	_	Evolves Hydrogen See also 315 (B/5 applies), 1306, 1403 and 1404
CROTONALDEHYDE CH3CHCHCHO	_	х	х	х	-	-	See 1306
1,2 DICHLOROPROPANE	1,16	×	×	x		Al	See 1306
CH₃CHClCH₂Cl	-1.0	,		.,			

LLOYD'S REGISTER OF SHIPPING

1	2 -	3	4	5	6	7	8
Name Formula	Specific Gravity where over 1,025	Fire Hazard	Vapour Hazard	Skin Contact Hazard	Water Reac- tivity Hazard	Unsuitable Materials	Additional requirements, information, etc.
1,3 DICHLOROPROPENE CHClCHCH₂Cl	1,23	x	x	x	-	Attacks mild steel if water present	See 1306
Maryura mulaim							0,000,00
EPICHLOROHYDRIN C ₃ H ₅ OCl	1,18	×	×	×	-	-	See 1306, 1403 and 1404
ETHYLENE DIBROMIDE CH ₂ BrCH ₂ Br	2,17	-	×	х	_	-	See 1306 and 1403
ETHYL ACRYLATE CH ₂ CHCOOC ₂ H ₅		×	X	x		_	Inhibited for shipment
ETHYLENEDIAMINE NH ₂ CH ₂ CH ₂ NH ₂		х		х	-	Cu	HOLITADA
ETHYLENE DICHLORIDE CH ₂ ClCH ₂ Cl	1,26	х	Х	-		Cu	See 1403
Day of the Estate of the Land							Manual de la constant
FORMIC ACID HCOOH	1,22		×	x		Mild steel	Stainless Steel acceptabl also Aluminium for concentrations > 98%
METHYL ACRYLATE CH ₂ CHCOOCH ₃		Х	х .	x			Inhibited for shipment
METHYL METHACRYLATE CH ₂ C(CH ₃)COOCH ₃		х	х	1.1		Cu	Inhibited for shipment
				- 1			
NITRIC ACID (70% AQ SOL and OVER) HNO ₃	1,5	-	X	X	T-	Mild steel	Strong oxidizing agent Stainless Steel acceptabl See 1403 and 1404
							arrow directions
OLEUM H ₂ SO ₄ +SO ₃	1,98		x	×	х	Mild steel for conc. less than 98%	Mild Steel acceptable for conc. 98% or more Stainless Steel acceptable for all conc. Evolves Hydrogen See also 1403 and 1404

1	2	3	4	5	6	7	8
Name Formula	Specific Gravity where over 1,025	Fire Hazard	Vapour Hazard	Skin Contact Hazard	Water Reac- tivity Hazard	Unsuitable Materials	Additional requirements, information, etc.
PHENOL C ₆ H ₅ OH	1,05	-	x	x		Al Cu Zn	Heated Cargo (Freezing point 41°C (106°F)) See 1306, 1403 and 1404
PHOSPHORIC ACID (85%) H ₃ PO ₄	1,7			х		Mild steel	Stainless Steel acceptable or Rubber Linings Heated Cargo Freezing point 23°C (74°F
PHOSPHORUS TRICHLORIDE PCl ₃	1,57	-	х	х	х	Mild Steel Al Zn	Inerted for shipment (Dry Nitrogen) Nickel acceptable
PHOSPHORYL CHLORIDE POCl ₃	1,67		х	х	х	Mild Steel Al Zn	Inerted for shipment (Dry Nitrogen) Nickel acceptable
PROPIONIC ACID CH₃CH₂COOH				x	-	Mild Steel	Stainless Steel or Aluminium acceptable
SULPHURIC ACID H ₂ SO ₄	1,84	_	-	Х	X	Mild Steel for cone. less than	Mild Steel for conc. 98% or more Stainless Steel acceptable for all conc.
SULPHUR TRIOXIDE SO ₃	1,83		x	х	х	98%	(Evolves Hydrogen) Inhibited for shipment Normal carrying temp. 30°-35°C (86°-95°F)
PRO-DITE AND DESCRIPTION -						1011245	
TOLYLENE DI-ISOCYANATE CH ₃ C ₆ H ₃ (NCO) ₂	1,22	- ,	x	х	х	-	Inerted for shipment (Dry Nitrogen) Normal carrying temp. 20°-25°C (68°-77°F)
						2577749	D ₁ H ₂ H ₂ H ₂ H ₃
							TEAN NEWS

LLOYD'S REGISTER OF SHIPPING

1	2	3	4	5	6	7
Name Formula	Specific Gravity where over 1,025	Fire Hazard	Vapour Hazard	Skin Contact Hazard	Unsuitable Materials	Additional requirements information, etc.
ADIPONITRILE CN(CH ₂) ₄ CN	-	_	×	x		Lucilles Lucilles (Inches)
AMMONIA 30% SOL. NH ₄ OH	-	_	×	х	Cu Zn Nickel	Absolute vapour pressure at 30°C (86°F)=15·8 p.s.i.
BENZENE C_6H_6		x	x	-	-	706 applies for pump room ventila- tion See 1306
iso-BUTYRALDEHYDE $(CH_3)_2CHCHO$		x		x	-	
n-BUTYRALDEHYDE CH ₃ (CH ₂) ₂ CHO		х		х	-	and transmit
CARBON TETRACHLORIDE CCl ₄	1,59	-	x		Al Zn	706 applies for pump room ventila- tion See 1306
CHLOROBENZENE C_6H_5Cl	1,11	х	x	_	-	
CHLOROFORM CHCl ₃	1,48	-	× .		-	See 1306
p-CRESOLS (pCRESYLIC ACID) (mixed isomers) CH ₃ C ₆ H ₄ OH	1,05		_	х	-	Freezing point 20°C-34°C (68°F-92°F)
CUMENE C ₆ H ₅ CH(CH ₃) ₂		x	×	_	_	STANLED SHE IN THE PARTY OF
CREOSOTE	1,10		=	×		
2,2 DICHLOROETHYL ETHER CICH ₂ CH ₂ OCH ₂ CH ₂ Cl	1,22		x	х		
DIETHANOLAMINE (HOCH ₂ CH ₂) ₂ NH	1,1		_	×	Cu Zn	
DIETHYLAMINE (C ₂ H ₅) ₂ NH	-	×	_	x	Al Cu Zn	a Table (Assessment)

1		2	3	4	5	6	7
Name Formula		Specific Gravity where over 1,025	Fire Hazard	Vapour Hazard	Skin Contact Hazard	Unsuitable Materials	Additional requirements information, etc.
DIETHYLENE TRIAMINE NH ₂ CH ₂ CH ₂ NHCH ₂ CH ₂ NHC		- 1	-	-	x	Cu	
DIMETHYLAMINE 40% AQ $(CH_3)_2NH$			х	х	х	Al Cu Zn	See 1306
$\begin{array}{c} {\rm DIMETHYLAMINOETHANOL} \\ {\rm (CH_3)_2NCH_2CH_2OH} \end{array}$	m		х		х	Cu	HARDADE ACADEM JANUARA
DIMETHYL FORMAMIDE $HCON(CH_3)_2$		-	х	-	х		
					IV.		DIANTHOROLISIA PAR
2 ETHYL 3 PROPYL ACROLEIN $CH_3(CH_2)_2CHC(C_2H_5)CHO$		-	х	х	-		Mastriosor Zickerst
ETHYLENE CYANOHYDRIN CH ₂ OHCH ₂ CN	ax min	1,04	х	х	х	-	STRUMENTS TO STRUMENTS OF
FORMALDEHYDE SOL 37% HCHO		1,11	х	х	х	·	miretour par-
$FURFURAL$ C_4H_3OCHO		1,16	X	х	-	-	
$\begin{array}{c} \mathrm{FURFURYL} \ \mathrm{ALCOHOL} \\ \mathrm{C_4H_3OCH_2OH} \end{array}$		1,13	_	х	-	Al	
MORPHOLINE (CH ₂) ₄ ONH			х		x	Cu Zn	
$ m NITROBENZINE \ C_6H_5NO_2$		1,20	-	х	x	_	
PENTACHLOROETHANE CHCl ₂ CCl ₃		1,68		х			
PROPIONALDEHYDE C ₂ H ₅ CHO		-	х	-	х		Inerted for shipment (Dry Nitrogen) Boiling point 49°C (120°F)

LLOYD'S REGISTER OF SHIPPING

1 Name Formula		Specific Gravity where over 1,025	3 Fire Hazard	Vapour Hazard	5 Skin Contact Hazard	6 Unsuitable Materials	7 Additional requirements information, etc.
PYRIDINE (99% conc.) N(CH) ₄ CH			x		х	Cu	- APÉRALET POPLECIONES
							THE ROLL OF THE PARTY OF
STYRENE MONOMER C ₆ H ₅ CHCH ₂		=.	×	x		Cu	Inhibited for shipment
TETRACHLOROETHANE CHCl ₂ CHCl ₂		1,59	-	×	_	Cu	
TETRAHYDROFURAN $(C_2H_4)_2O$		_	x	x	-	-	Inhibited for shipment
TRIETHYLENE TETRAMINE NH ₂ (C ₂ H ₄ NH) ₃ H		-	_	-	x	Al Cu Zn	
iso-VALERALDEHYDE (CH ₃) ₂ CHCH ₂ CHO			x	x	х	-	100 70 100 100 100 100 100 100 100 100 1
n-VALERALDEHYDE CH ₃ (CH ₂) ₃ CHO			x	х	х	-	0B50,15
	1			١.			Ho,Goo,H
							Statuta - sta
							TE AND STRUCTURE
College Control of the College						,	
							L montingonnerin
The second second	t						0.000

1 Name Formula		Specific Gravity where over 1,025	3 Fire Hazard	4 Unsuitable Materials	5 Additional requirements, information, etc.
ACETONE CH ₃ COCH ₃		-	×	_	
AMYL ACETATE-iso CH ₃ COO(CH ₂) ₂ CH(CH ₃) ₂		-	×	_	TOTAL ALTOHOLOGY
AMYL ACETATE-sec CH ₃ COOCH(CH ₃)C ₃ H ₇		_	x	_	
AMYL ACETATE-n CH ₃ COOC ₅ H ₁₁		_	×	-	MTATERA ARBITRADA AFETTA
AMYL ALCHOHOL-n CH ₃ (CH ₂ CH ₂)OH		127	х		Mirror Alvani
AMYL ALCOHOL-p, iso (CH ₃) ₂ CHCH ₂ CH ₂ OH		_	×	_	RTATY/IZAILTON TETTLE
AMYL ALCOHOL-sec, n (CH ₃ CH ₂) ₂ CHOH		-	x	_	HTAMARITH CYTCH
AMYL ALCOHOL-sec, iso (CH ₃) ₂ CHCHOHCH ₃		_	х	-	
AMYL ALCOHOL-tert (CH ₃) ₂ C ₂ H ₅ COH		_	х	_	and remarked
ASPHALT	icuro.	Up to 1,10	See column 5	-	Heated cargo Flash point depends upon grade
Committee of the Commit		*			AKATAMANYO OLO
					Part Care Service District Control of Contro
					AGRAZIBIO SYC
BUTYL ACETATE-iso CH ₃ COOCH ₂ CH(CH ₃) ₂		-	×	-	0,10
BUTYL ACETATE-n CH ₃ COOC ₄ H ₉		-	х	_	AT MEN TOTAL
BUTYL ACETATE-sec CH ₃ COOCH(CH ₃)(C ₂ H ₅)		-	×	_	
BUTYL ALCOHOL-iso CH ₃ CHCH ₂ OH	1111-		х	_	dotrongs agreeme
BUTYL ALCOHOL-n CH ₃ CH ₂ CH ₂ CH ₂ OH		-	х	-	is party, anomol.

1		2	3	4	5
Name Formula		Specific Gravity where over 1,025	Fire Hazard	Unsuitable Materials	Additional requirements, information, etc.
BUTYL ALCOHOL-sec CH ₃ CH ₂ CHOHCH ₃		-	×	_	(ENOTED)
BUTYL ALCOHOL-tert (CH ₃) ₂ COHCH ₃		-	x	(—)	ALTOROGE AT A
BUTYL BENZYL PHTHALATE C ₄ H ₉ COOC ₆ H ₄ COOCH ₂ C ₅ H ₅		1,12	-		11, X, to inexcept
BUTYL DIGLYCOL ACETATE $C_4H_9O(CH_2)_2O(CH_2)_2OCOCH_3$		_	_	-	HOOOLIII.
BUTYL ETHER CH ₃ (CH ₂) ₃ O(CH ₂) ₃ OH ₃		-	x	N	Inhibited for shipment
BUTYL METHACRYLATE CH ₂ C(CH ₂)COOC ₄ H ₉	×	-	×	_	Inhibited for shipment
BUTYL PHTHALATE $C_6H_4(COOC_4H_9)_2$		1,05	-	-	nonnigma.
					HA SINCERCHICIA,
CAMPHOR OIL		1,04 max.	x		THE OWNER OF THE PERSON OF THE
CAUSTIC SODA 55% NaOH		1,53	10	Cu Al Zn	If heated, temp. not to exceed 55°C (131°F)
CYCLOHEPTANE C7H14		_	X	-	
$ ext{CYCLOHEXANE} \\ ext{C}_6 ext{H}_{12} ext{}$		-	х	-	
$ ext{CYCLOHEXANOL} \\ ext{C}_6 ext{H}_{11} ext{OH} $		-	=	-	
$ ext{CYCLOHEXANONE} \\ ext{C}_6 ext{H}_{10} ext{O}$		Τ.	×		DEDIEVE TELEVISION
p-CYMENE CH ₃ C ₆ H ₄ CH(CH ₃) ₂	. T ×	-	×	-	n-Eram V. dere
	# #				The state of the s
n-DECYL ALCOHOL CH ₃ (CH ₂) ₈ CH ₂ OH	¥.	-	-		TOTAL CHICAGON
iso-DECYL ALCOHOL C ₁₀ H ₂₁ OH		-	×	-	S-CORROLL STYLE

i Name Formula	Specific Gravity where over 1,025	3 Fire Hazard	4 Unsuitable Materials	5 Additional requirements, information, etc.
DIACETONE ALCOHOL CH ₃ COCH ₂ C(CH ₃) ₂ OH	_	x		
DIBUTYLAMINE (C ₄ H ₉) ₂ NH		х	-	
$\begin{array}{c} \text{Di-iso-BUTYL PHTHALATE} \\ \text{C}_6\text{H}_4[\text{COOCH}_2\text{CH}(\text{CH}_3)_2]_2 \end{array}$	1,04	-	:>	HEATEDA STAVE
$_{1,2} \ _{\rm DICHLOROBENZENE} \\ _{\rm C_6H_4Cl_2}$	1,31	_	(JOHNSON AVILYS
$ \begin{array}{c} \mathrm{DICYCLOPENTADIENE} \\ \mathrm{C_{10}H_{12}} \end{array} $	-	x	-	ARTHUR ARTIST
DIETHYLBENZENE $C_6H_4(C_2H_5)_2$		х	-	ADAZHIO DIA ATRICA
DIETHYLENE GLYCOL CH2OHCH2OCH2CH2OH	1,12	-		
DIETHYLENE GLYCOL METHYL ETHER CH ₃ OCH ₂ CH ₂ OCH ₂ CH ₂ OH	1,04		-	ATA TRANSPORT THE ATA ATA ATA
DIETHYLENE GLYCOL MONOBUTYL ETHER $C_4H_9OCH_2CH_2OCH_2CH_2OH$			1-1	. Indicate a Recurring
DIETHYLENE GLYCOL MONOETHYL ETHER CH ₃ CH ₂ OCH ₂ CH ₂ OCH ₂ CH ₂ OH	1,03	-	TAIL	The control of the second seco
DIISOBUTYLENE Compound of C ₈ H ₁₆	-	х	TI-SIN	Transconductoring and particular
DIISOPROPANOLAMINE (CH ₃ CHOHCH ₂) ₂ NH	_	_	Cu	Heated Cargo Freezing point 40°C (108°F)
DIISOBUTYLKETONE [(CH ₃) ₂ CHCH ₂] ₂ CO	-	х	_	
DIISOOCTYL PHTHALATE $C_6H_4(COOC_8H_{17})_2$	=	=	-	ALOREM PROPERTY OF
DIPENTENE $C_{10}H_{16}$	_	х	121610	TO HOLD STORY OF THE STORY OF T
DIPROPYLENE GLYCOL (CH ₃ CHOHCH ₂) ₂ O	-	-	1500	Children arren and children
DIPROPYLENE GLYCOL METHYL ETHER CH ₃ OC ₃ H ₆ OC ₃ H ₆ OH	-	-		HOURS, THE PERSON
DODECYL ALCOHOL $CH_3(CH_2)_{11}OH$	-	_		

Name Formula	Specific Gravity where over 1,025	3 Fire Hazard	4 Unsuitable Materials	5 Additional requirements, information, etc.
DODECYL BENZENE $C_{12}H_{25}C_6H_5$	_	-		ROPOTAL INFOTALIO
TO THE PARTY OF TH	7			THE RESERVE OF THE PARTY OF THE
ETHYL ACETATE CH ₃ COOC ₂ H ₅		x		BLADING BOTTO
ETHYL ALCHOHOL C_2H_5OH	2 ==	×	-	St assemble made at
ETHYL BENZENE C ₆ H ₅ C ₂ H ₅	=	x	-	SEE SEE SEE SEE SEE SEE SEE
ETHYL CYCLOHEXANE $C_2H_5C_6H_{11}$	1	X		(LE) (E)
2-ETHYL HEXYL ACRYLATE CH ₂ CHCO ₂ CH ₂ CH(C ₂ H ₅)C ₄ H ₉			_	EO, IC), IC O, IC
ETHYLENE CARBONATE (CH ₂ O) ₂ CO	1,32	307	_	maren november 181
ETHYLENE GLYCOL CH₂OHCH₂OH	1,13	_		HO, ID, I-10, HO, HOO, HY
ETHYLENE GLYCOL MONOBUTYL ETHER C ₄ H ₉ OCH ₂ CH ₂ OH	1-	×		THE STATE OF THE S
ETHYLENE GLYCOL MONOBUTYL ETHER ACETATE C ₄ H ₉ O(CH ₂) ₂ OOCCH ₃	×-		_	pligo to Leavest
ETHYLENE GLYCOL MONOETHYL ETHER CH ₂ OHCH ₂ OC ₂ H ₅		×		HACTORIO POR CONTROL OF CONTROL O
ETHYLENE GLYCOL MONOETHYL ETHER ACETATE CH ₃ COOCH ₂ CH ₂ OC ₂ H ₅	_	x	;—:	BYANGER AT COOKING
ETHYLENE GLYCOL MONOMETHYL ETHER CH ₃ OCH ₂ CH ₂ OH	-	×	-	interpolation of the second
ETHYLENE GLYCOL MONOPHENYL ETHER C ₆ H ₅ O(CH ₂) ₂ OH		_		Alexandranae devices
2-ETHYL HEXANOL CH ₃ (CH ₂) ₃ CHC ₂ H ₃ CH ₂ OH	1-1	-	-carr	A ANGELIA CONTRACTOR ADDRESS A STREET, I
THE ADMINISTRATION OF THE PARTY	141			JOHNALL LYSKOP

Name Formula		Specific Gravity where over 1,025	3 Fire Hazard	4 Unsuitable Materials	5 Additional requirements, information, etc.
GLYCERINE (GLYCEROL) $C_3H_5(OH)_3$		1,26	_	_	May require heating Melting point 18°C (65°F)
					DEIGHTS LYRTH-C LYRTHE
HEPTANE-n CH ₃ (CH ₂) ₅ CH ₃		_	х		MCHORNOLARINE MC
HEPTENE (MIXED ISOMERS) C_7H_{14}			х	_	
HEPTYL ALCOHOL-n $CH_3(CH_2)_5CH_2OH$		-	х	-	BURETOURSED ATTENDES
HEXANE-iso CH ₃ (CH ₂) ₂ CH(CH ₃) ₂		_	х	-	DIAT JANO TRANSPARENT
HEXENE-1 CH ₂ CH(CH ₂) ₃ CH ₃		-	х	-	CAPITALATAINE (MITTER)
HEXYL ALCOHOL-n CH ₃ (CH ₂) ₄ CH ₂ OH		Ŧ.	х	-	BY A IL THINK PARTY.
$\begin{array}{c} {\rm HEXYLENE~GLYCOL} \\ {\rm (CH_3)_2COHCH_2CHOHCH_3} \end{array}$		F	TT.		invaloration Ele
					FAURA TO PEROTE IN
METHYL ACETATE CH ₃ COOCH ₃	10	N.	х	-	E-STRANGEROUS STREET
METHYL ALCOHOL CH ₃ OH			х	-	Wide flammable range
$\begin{array}{c} \text{METHOXYTRIGLYCOL} \\ \text{CH}_3\text{O}(\text{C}_2\text{H}_4\text{O})_3\text{H} \end{array}$		1,05	_		Sychiatra moximum
METHYL AMYL ACETATE CH ₃ COOCH(CH ₃)CH ₂ CH(CH ₃) ₂		_	х	-	Johnson School
METHYL AMYL ALCOHOL (CH ₃) ₂ CHCH ₂ CH(CH ₃)OH			х		TOWNSHE TARON
METHYL ETHYL KETONE CH ₃ COC ₂ H ₅		-	х	-	
METHYL ISOBUTYL KETONE CH ₃ COCH ₂ CH(CH ₃) ₂		-	х	-	MATION
MONOETHANOLAMINE HOCH ₂ CH ₂ NH ₂	-	-	-	Cu Zn	IDIR TOUR

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Name Formula		Specific Gravity where over 1,025	3 Fire. Hazard	4 Unsuitable Materials	5 Additional requirements, information, etc.
METHYLMETHACRYLATE CH ₂ C(CH ₃)COOCH ₃		-	×	:	Inhibited for shipment
2-METHYL 5-ETHYL PYRIDINE CH ₃ C ₅ H ₃ NC ₂ H ₅		-	-	_	
MONOISOPROPANOLAMINE CH₃CHOHCH₂NH₂		-	-		The state of the s
Torti diagrami					Mario di artir le con
NAPHTHA (PETROLEUM)		=	х		= 10 decire - 177-00 E0,000,000,00
NAPHTHA (SOLVENT) (COAL TAR)	÷		х	-	Amir Milita
NAPHTHALENE (MOLTEN) $C_{10}H_8$		1,15	х		Melting point 80°C (176°F) Fire hazard relates to carriage temp. above flash point
NITROETHANE CH ₂ CH ₂ NO ₂	18	1,05	х	Cu	0.07(0.07)
NITROMETHANE CH ₃ NO ₂		1,14	x	-	ARTHOROGENESIS.
NITROPROPANE-1 CH₁CH₂CH₂NO₂		-	х	Cu	
NITROPROPANE-2 (CH ₃) ₂ CH ₂ NO ₂		-	х.	Cu	
NONANE-n C ₉ H ₂₀		_	х	_	10000114
i-NONENE (NONYLENE) C ₉ H ₁₈		_	_	_	The state of the s
NONYL ALCOHOL C ₉ H ₁₉ OH			-	41 <u></u>	AND HARD ROLL OF
NONYL PHENOL $C_9C_6H_{19}H_4OH$		_	-	-	Normally heated up to a max. of 40°C (104°F)
iso-OCTANE C_8H_{18}	*	-	x	_	
OCTENE C ₈ H ₁₆	- 40	-	×	777	THE THE PROPERTY OF THE PARTY O

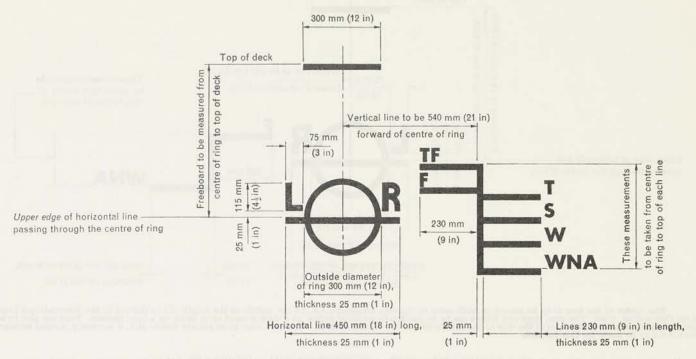
1 Name Formula	Specific Gravity where over 1,025	3 Fire Hazard	4 Unsuitable Materials	Additional requirements, information, etc.
$\begin{array}{c} {\rm OCTYL\ ALCOHOL} \\ {\rm CH_3(CH_2)_3CHC_2H_5CH_2OH} \end{array}$	_	ELS.		SHIP TO VALLED IN
				HARKSEIN LYHERIKE
PERCHLOROETHYLENE C_2Cl_4	1,62	_	-	CACOTTO RELEGIORES
POTASSIUM HYDROXIDE 50% KOH	1,54	-	Al Zn	Py Exitinguisting
PROPYL ACETATE-i CH ₃ COOCH(CH ₃) ₂		х	-	Talling's asia of 1700E
PROPYL ACETATE-n CH ₃ OOCC ₃ H ₇		х	- 111	THE RESERVE TO A PROPERTY OF THE PERSON NAMED
PROPYL ALCOHOL-i (CH ₃) ₂ CHOH		х		
PROPYL ALCOHOL-n C ₃ H ₇ OH	_	х	_	STATEM AFFER
PROPYLENE GLYCOL CH₃CHOHCH₂OH	1,04	_		Ben Livr Avery
PROPYLENE GLYCOL MONOMETHYL ETHER CH ₃ OCH ₂ CHOHCH ₃		x		
				e manage
	1			estruy
TETRAHYDRONAPHTHELENE $C_{10}H_{12}$	_	-	_	
$\begin{array}{c} \text{TETRAPROPYLENE} \\ \text{C}_{12}\text{H}_{24} \end{array}$		х	_	
TOLUENE C ₆ H ₅ CH ₃	-	х	_	
TRICHLOROETHANE 1, 1, 1 CH ₃ CCl ₃	1,46	-	Al	Aluminium acceptable if cargo inhibited
TRICHLOROETHYLENE C_2HCl_3	1,47		-	
TRIDECYL ALCOHOL C ₁₂ H ₂₅ CH ₂ OH	-	· .—.	_	

Name Formula	Specific Gravity where over 1,025	3 Fire Hazard	4 Unsuitable Materials	Additional requirements, information, etc.
$\begin{array}{c} TRIETHANOLAMINE \\ (HOC_2H_4)_3N \end{array}$	1,13	-	Cu	HO, NO, OHO, ATTEN
TRIETHYL BENZENE $C_6H_3(CH_2CH_3)_3$				
TRIETHYLENE GLYCOL $C_6H_{14}OH$	1,12	W-+	-	NAME AND A STATE OF S
TRIPROPYLENE C_9H_{18}	4	х		The Bullyouth Muley and
TRIPROPYLENE GLYCOL $C_9H_{20}O_4$		-	-	- I-STRATIONALLY CONT.
TRIPROPYLENE GLYCOL MONOMETHYL ETHER HO(C ₃ H ₆ O) ₂ C ₃ H ₆ OCH ₃	+	-		a-STATEDA AVIOUR MADOUAL
				Name of the Party
VINYL ACETATE CH ₃ COOCHCH ₂		х	-	Inhibited for shipment
VINYL TOLUENE CH ₂ CHC ₆ H ₄ CH ₃		×	_	BO, HOAD BO, HI
				erocarcitoment
XYLENE-m C ₆ H ₄ (CH ₃) ₂	-	x	= 1	
$XYLENE-o$ $C_6H_4(CH_3)_2$		х	_	
$XYLENE-p$ $C_6H_4(CH_3)_2$	_	х		Melting point 13°C (55°F)
XYLENOL 3,5 (CH ₃) ₂ C ₆ H ₃ OH	1,04	-	2 <u>-</u>	Melting point varies May require heating
				u manual de la companya de la compan
				T, I AVAIREMENT DO N
				Avan Antaoneon Spri
				BONDARA STREET

ASSIGNMENT OF FREEBOARD

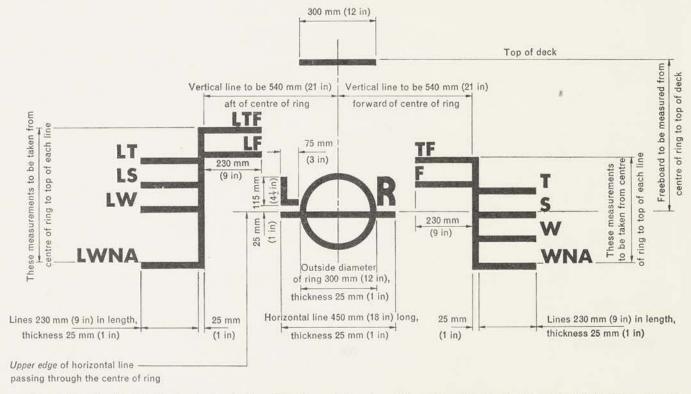
The Committee of Lloyd's Register are authorized to assign freeboards to British ships and to ships registered in other countries. Forms of application for the assignment of freeboard can be obtained from the London Office, or other offices of the Society.

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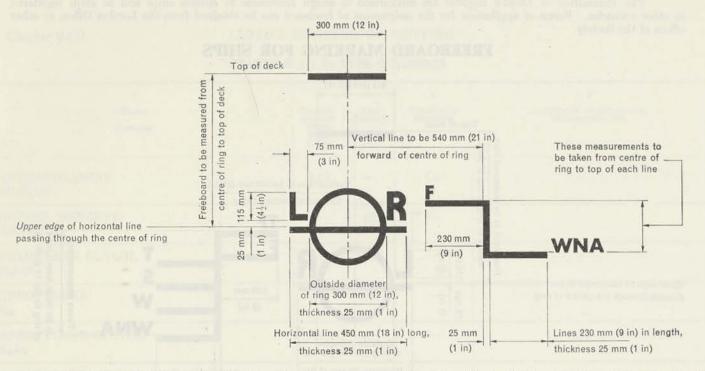
The centre of the ring is to be placed on both sides of the ship amidships, i.e., at the middle of the length (L) as defined in the International Load Line Convention, 1966. The ring, lines and letters are to be painted in white or yellow on a dark ground or in black on a light ground. They are also to be permanently marked on the sides of the ship to the satisfaction of the Administration. The marks are to be plainly visible and, if necessary, special arrangements are to be made for this purpose. Ships over 100 m (328 ft) in length are not required to be marked with the WNA line.

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